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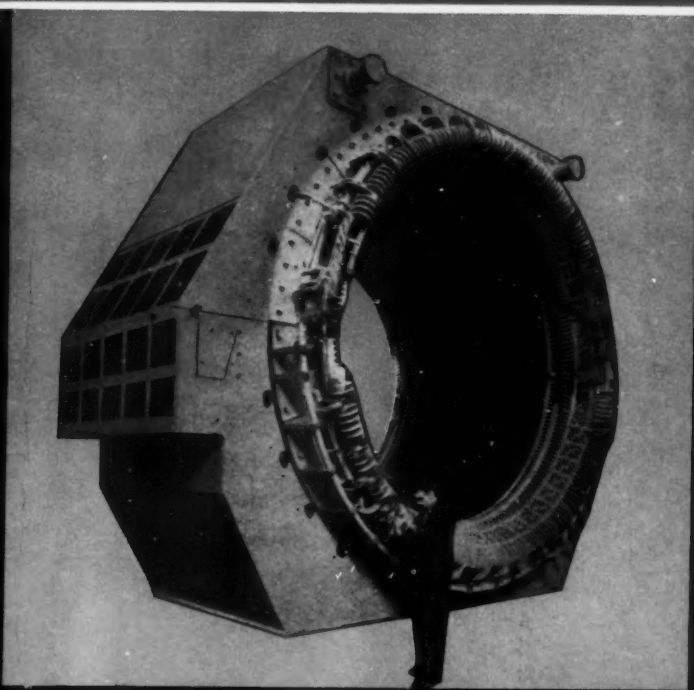
Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

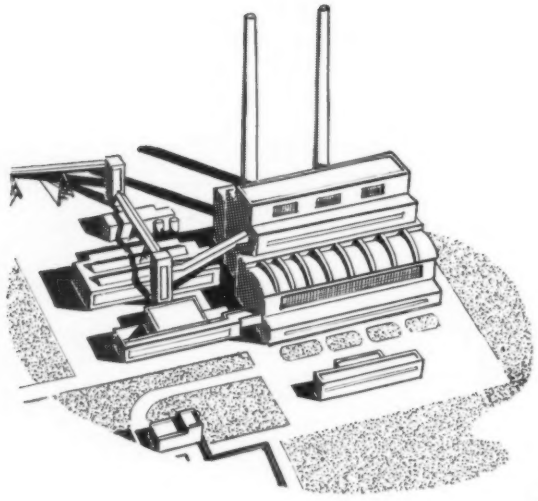
PRICE 2/6 SEPTEMBER 1960



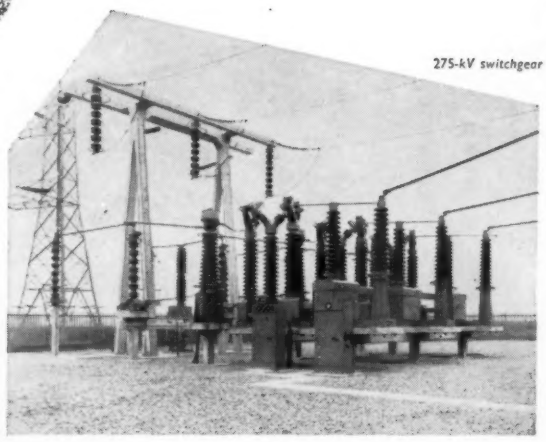
FOR
HYDRO-ELECTRIC
GENERATING
PLANT...

... RELY ON THE EXPERIENCE OF

G.E.C.

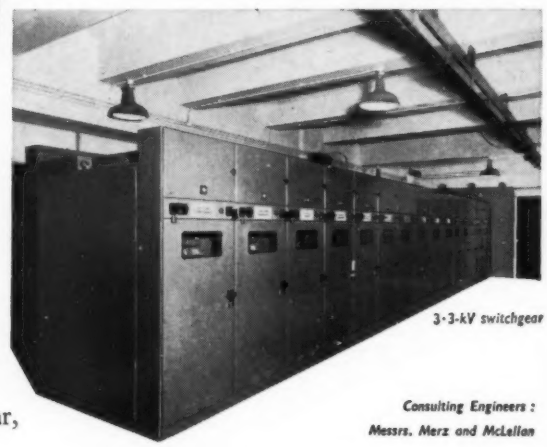


Blyth A
GENERATING STATION



275-kV switchgear

Main control-room



3·3-kV switchgear

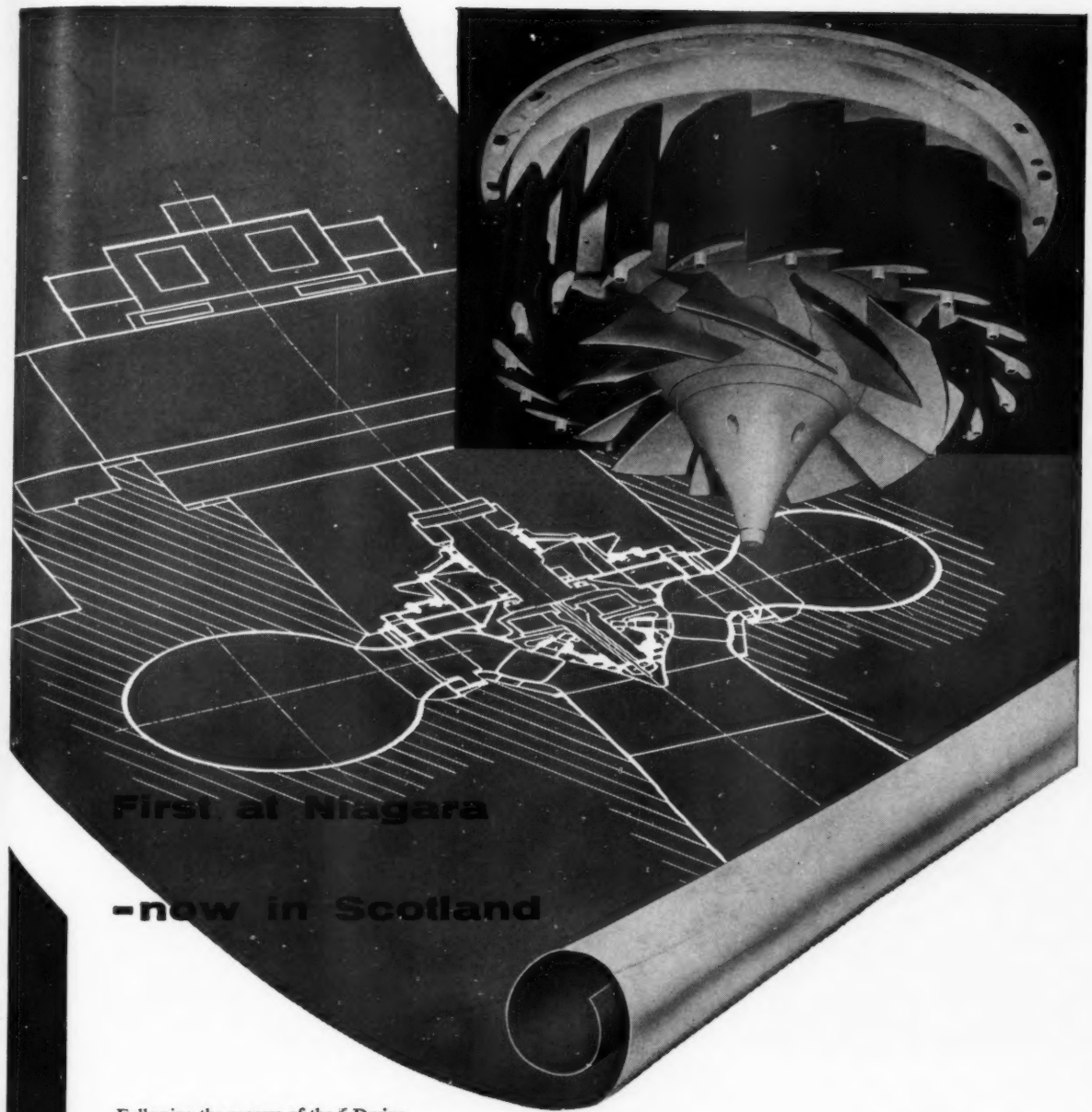
Reyrolle supplied the 275-kV air-blast switchgear, 66-kV small-oil-volume switchgear, 3·3-kV air-break auxilliaries switchgear, and 415-volt distribution gear together with associated control-equipment.

Consulting Engineers :
Messrs. Merz and McLellan

Photographs by courtesy of C.E.G.B., North Eastern Division

Reyrolle

A. REYROLLE & COMPANY LIMITED - HEBBURN - COUNTY DURHAM - ENGLAND



Following the success of the 6 Deriaz reversible pump turbines at Niagara, a 30,500 h.p., 180 feet head Deriaz turbine coupled to a 22 MW alternator has been ordered for the Culligran Power Station of the North of Scotland Hydro-Electric Board. A maximum efficiency of 91·7% was obtained on a 20-inch diameter model. This will be majorated as usual for the full-sized turbine.

'ENGLISH ELECTRIC'

hydro-electric equipment

THE ENGLISH ELECTRIC COMPANY LIMITED, MARCONI HOUSE, STRAND, LONDON, W.C.2

Hydro-Electric Department, Dunnings Bridge Road, Netherton, Bootle, 10

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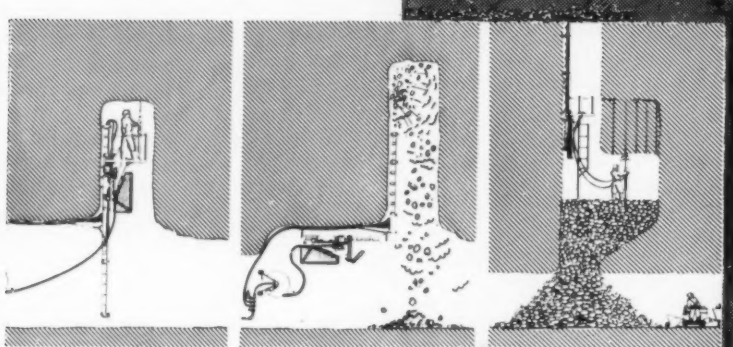

1. During the drilling, the drift miner works safely and efficiently on a stable platform.
2. At blasting, the elevator is in a well-protected position below the rock.
3. Stoping is done from below. The rock is removed successively down to the suitable working level.

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Export Department

SKELLEFTEÅ 3—SWEDEN

KARIBA—a stage completed

Another stage begun

Boving are supplying the six Water Turbines for Kariba, each of 140,000 h.p. Work is keeping pace with schedule and No. 3 turbine is approaching the completion stage.

Merz & McLellan—Electrical and Mechanical Consulting Engineers to the Federal Power Board.

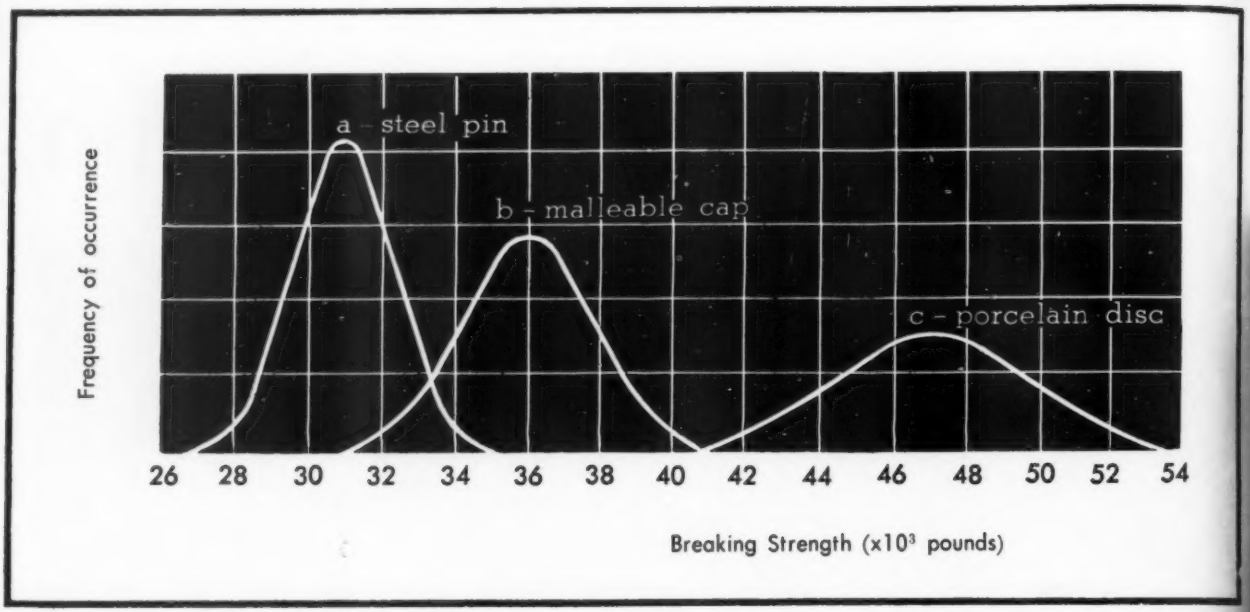
Boving

& CO LIMITED

VILLIERS HOUSE • 41-47 STRAND • LONDON WC2

P.4066

SUPERIORITY IN PORCELAIN


a - steel pin
b - malleable cap
c - porcelain disc
Frequency of occurrence
26 28 30 32 34 36 38 40 42 44 46 48 50 52 54
Breaking Strength (x10³ pounds)

UNIFORMITY
STRENGTH
DURABILITY

UNIFORMITY? ..... no matter how good an insulator you choose you can't expect maximum efficiency and service unless they're uniformly balanced in strength.

Take, as an example, the standard NGK 10″ ball and socket disc insulator (rated 25,000 lbs. E & M Strength) and review the mechanical strength of each component by the histogram above. Uniform mechanical breakdown strength, always occurring at the pin, of the NGK Insulator unit is shown by Curve a; that of the cap by Curve b when a special pin is used; that of the porcelain by Curve c when using a special high strength cap and pin.

Insulator uniformity at a high level is your prime assurance to safe operation and maintenance economy.

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Cable: INSULATOR Nagoya. TELEX: NGK-NG9928

Represented in all major territories

cross-channel power link

The submarine power cable to be laid across the Channel between Dungeness and Boulogne will be similar to the cable shown here. This cable, which now connects British Columbia with Vancouver Island, was manufactured and laid by BICC in unjointed 16-mile lengths.

The Central Electricity Generating Board and Electricité de France have placed contracts for the manufacture and laying of the cross-Channel submarine power link.

Two 100,000 volt single-core submarine power cables will put England and France on one electrical grid—a new balance of power to ease mutual problems of supply and demand.

With a capacity of 160 megawatts (over 200,000 h.p.) in either direction, this submarine circuit will carry the heaviest D.C. electrica load ever transmitted under water.

Cables for the British section will be made by two famous companies—BICC and AEI—working in close collaboration.

BICC

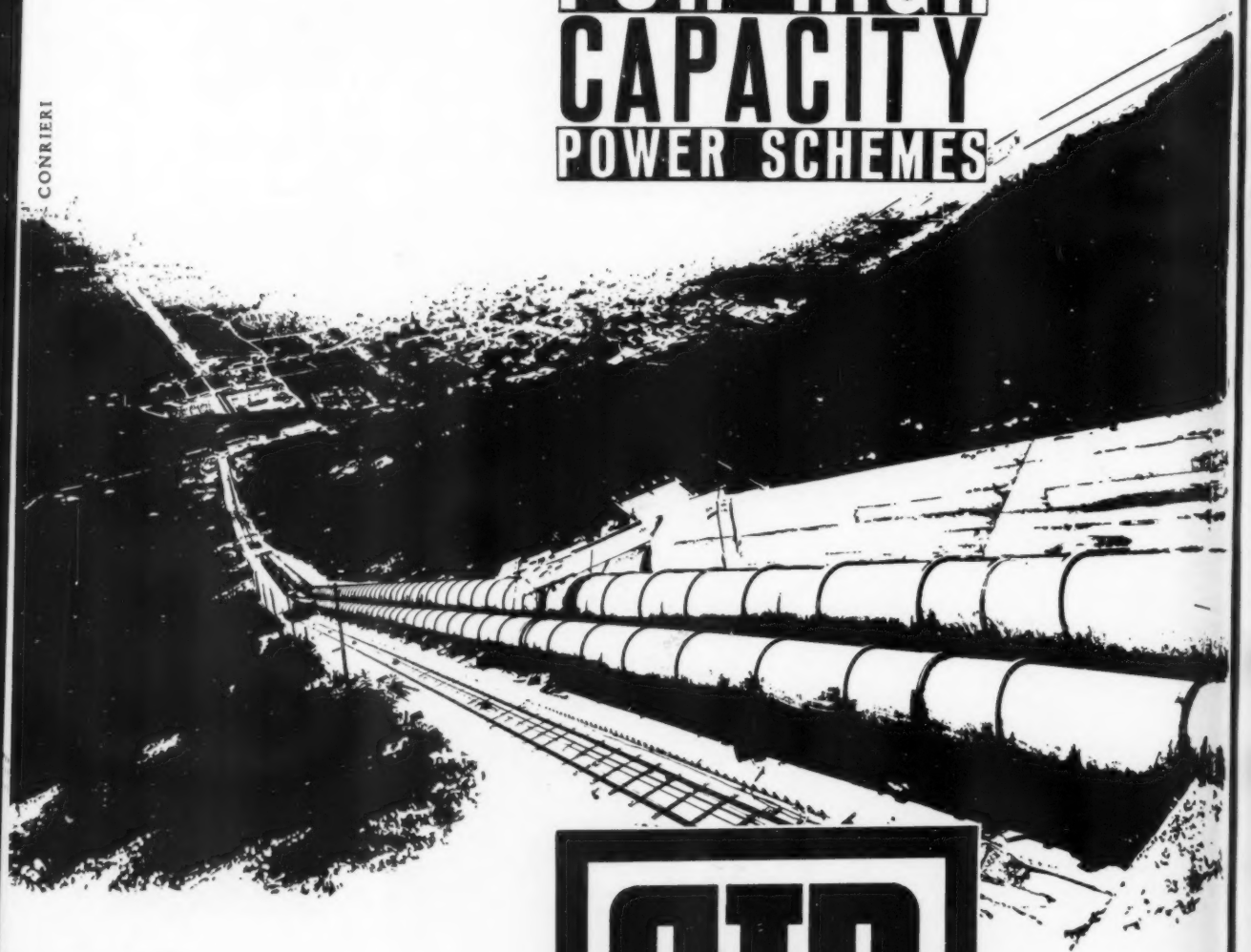
submarine

power cables

BRITISH INSULATED CALLENDER'S CABLES LIMITED 21 BLOOMSBURY STREET LONDON WC1

PENSTOCKS FOR HIGH CAPACITY POWER SCHEMES

CONRIERI



Sondrio Plant

ATB

Penstocks for high capacity power schemes - Large size valves and gates for hydraulic plants - Seamless steel cylinders for gases - Steel forgings - raw and machined castings of steel, cast-iron - Seamless rolled steel rings and flanges

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all the cable at Hunterston

is pg

19,500 yards of Pirelli-General 132 kV. single-core oil-filled cable are being installed between the transformers at the power station and switching station. The insulation of this cable is designed for 110 kV/cm. maximum working stress.

With the completion of this installation the whole of the cabling at Hunterston will have been carried out by Pirelli-General.

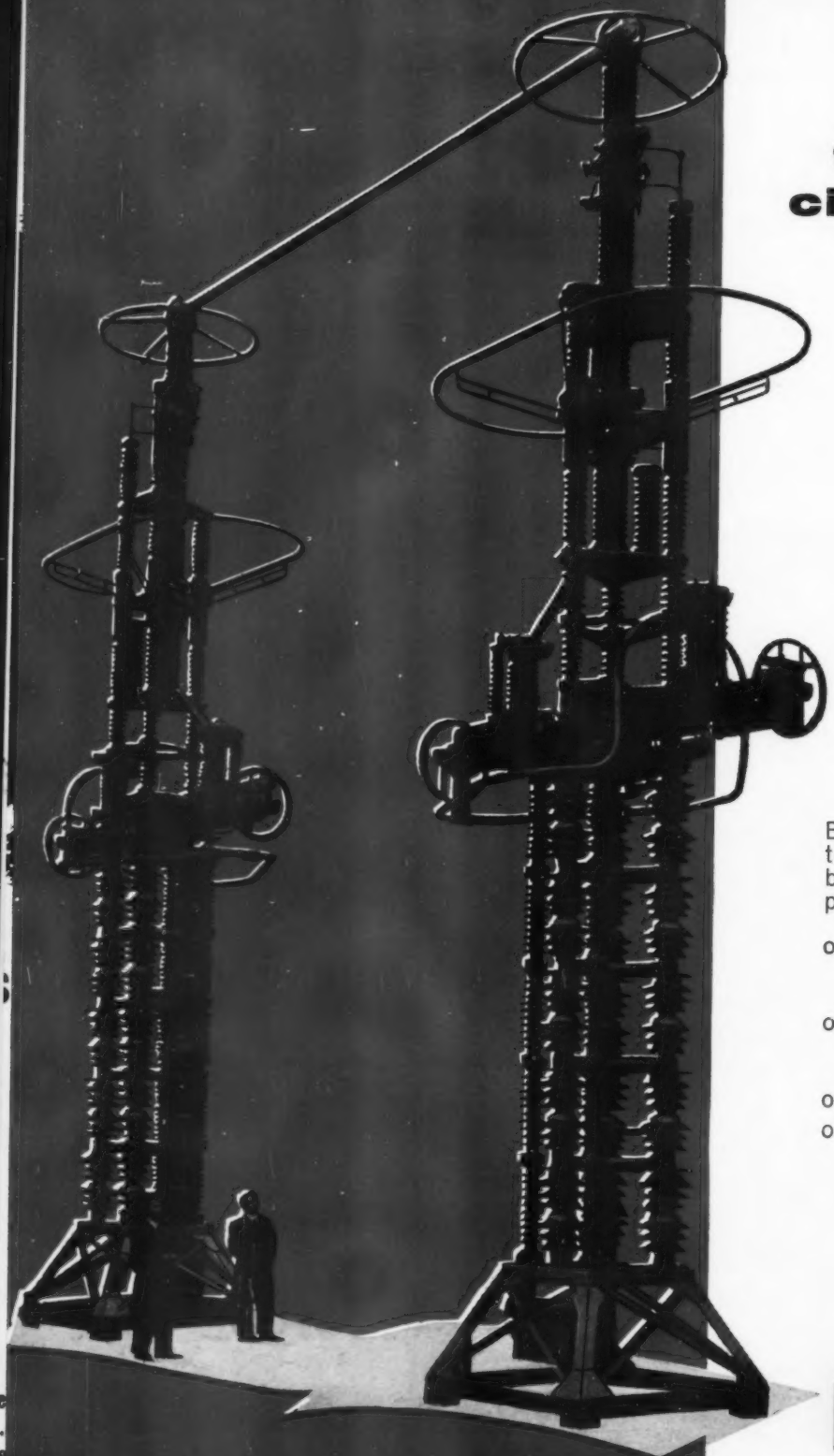
Hunterston is being constructed by the G.E.C.-Simon Carves Atomic Energy Group. Consulting Engineers to South of Scotland Electricity Board, Kennedy and Donkin.

pg

PIRELLI-GENERAL CABLE WORKS LIMITED

SOUTHAMPTON AND EASTLEIGH

FOR THE WORLD'S HIGHEST VOLTAGE RA



One of the poles of a series of 525 kV, 25,000 MVA, AE 17 air blast circuit breakers, for the equipment of the U.R.S.S network.

the air blast circuit breaker

type AE

A range of breakers from 70 kV to 525 kV

Breaking capacity: 30,000 amp. rms.

Besides properties peculiar to the technique of air blast circuit breakers the type AE apparaters provides:

- o Breaking with high r.r.r.v. and ability to interrupt a kilometric fault.
- o Breaking of currents in unloaded power transformers with low overvoltages
- o Low air consumption.
- o Negligible burning of contacts.

Ateliers de Constructions Electriques de

Delle

25 CHEMIN DE CYPRIAN VILLEURBANNE (RHONE)

OF THE "COMPAGNE

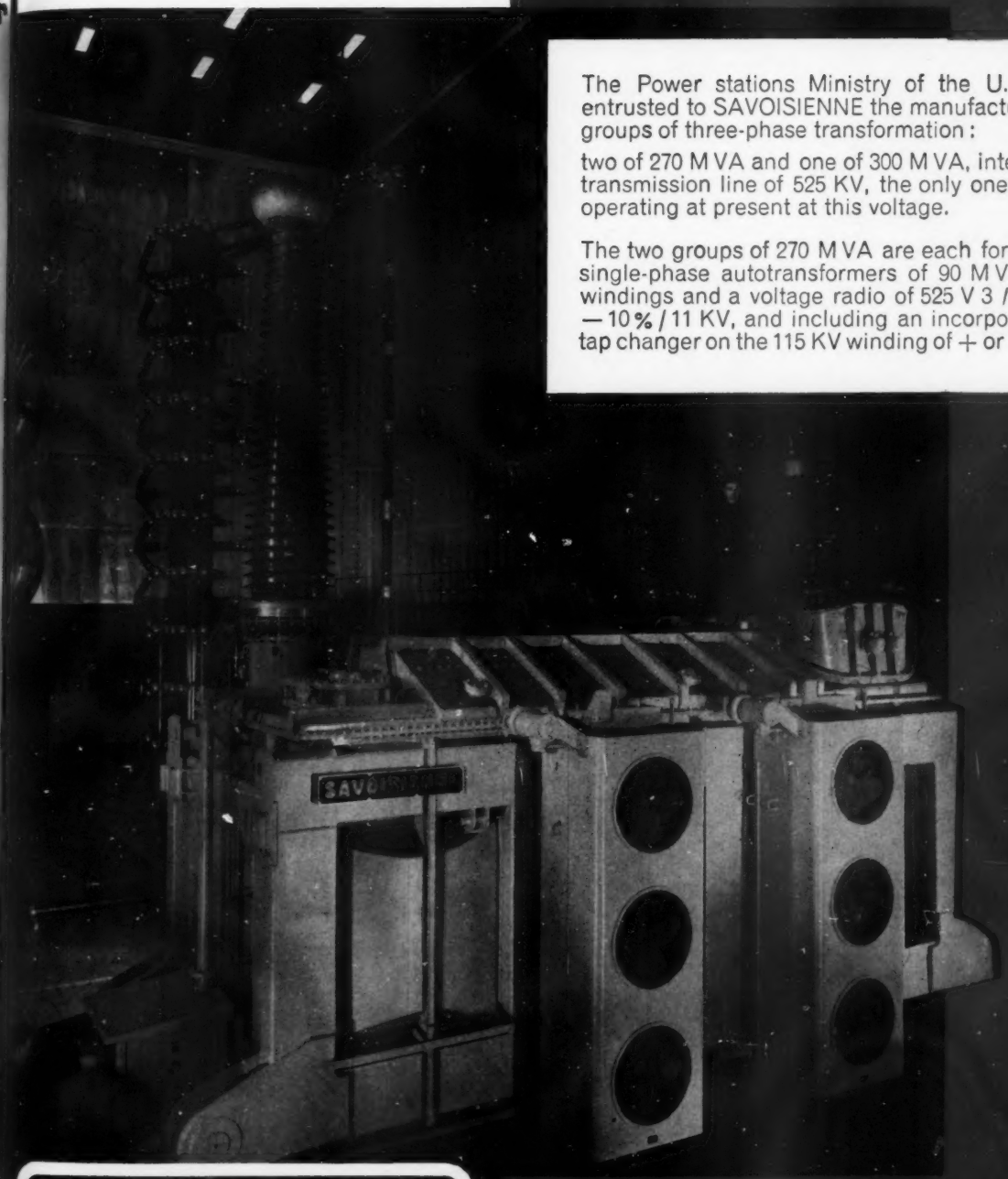
AGE

TRANSMISSION LINE 525 KV

The Power stations Ministry of the U. S. S. R. has entrusted to SAVOISIENNE the manufacturing of three groups of three-phase transformation :

two of 270 M VA and one of 300 M VA, intended for the transmission line of 525 KV, the only one in the world operating at present at this voltage.

The two groups of 270 M VA are each formed by three single-phase autotransformers of 90 M VA with three windings and a voltage radio of 525 V 3 / 115 V 3 + or — 10 % / 11 KV, and including an incorporated on-load tap changer on the 115 KV winding of + or — 10 % steps.

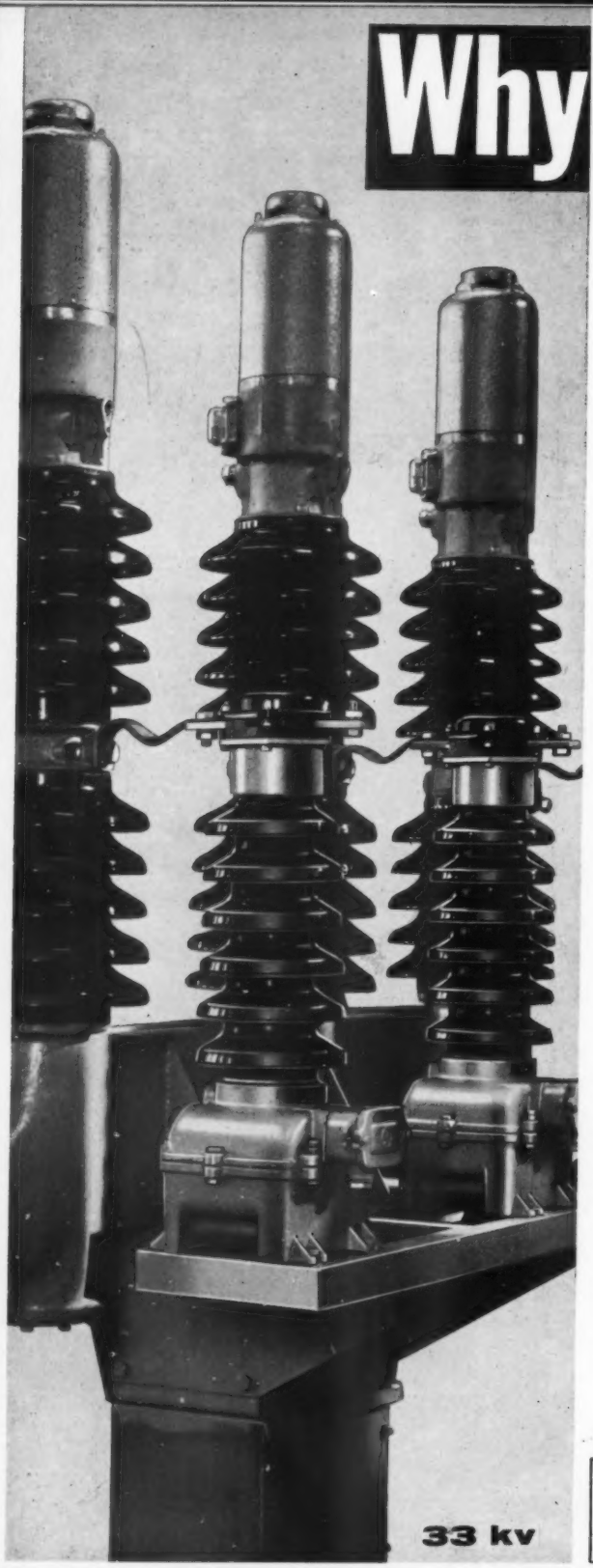


The first transformer has successfully supported the final tests in the new SAVOISIENNE laboratory at Aix-les-Bains equipped with an impulse voltage generator of 1.7 Kilojoules whose maximum voltage reaches 4, 400, 000 volts.

SAVOISIENNE

AIX-LES-BAINS (Savoie)

GENERALE D'ELECTRICITE"



Why does one choose sm ?

this is one of the many reasons...

The ratings of a circuit breaker can be validly supported only by suitable type tests proving the circuit breaker behaviour under the worst conditions which must be faced on service.

The MT circuit breakers (see illustration) of SCARPA e MAGNANO underwent, for each service voltage, the type tests required by the I. E. C. International Standards, at the official Laboratory of KEMA, in Holland.

The certificates proving the favourable result of these tests are kept by SCARPA e MAGNANO at the disposal of customers.

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PLEASE SEND ME INFORMATION ON:

☐ H. V. CIRCUIT BREAKERS ☐ ISOLATORS

☐ M. V. CIRCUIT BREAKERS ☐ INSTRUMENT AND PROTECTIVE TRANSFORMERS

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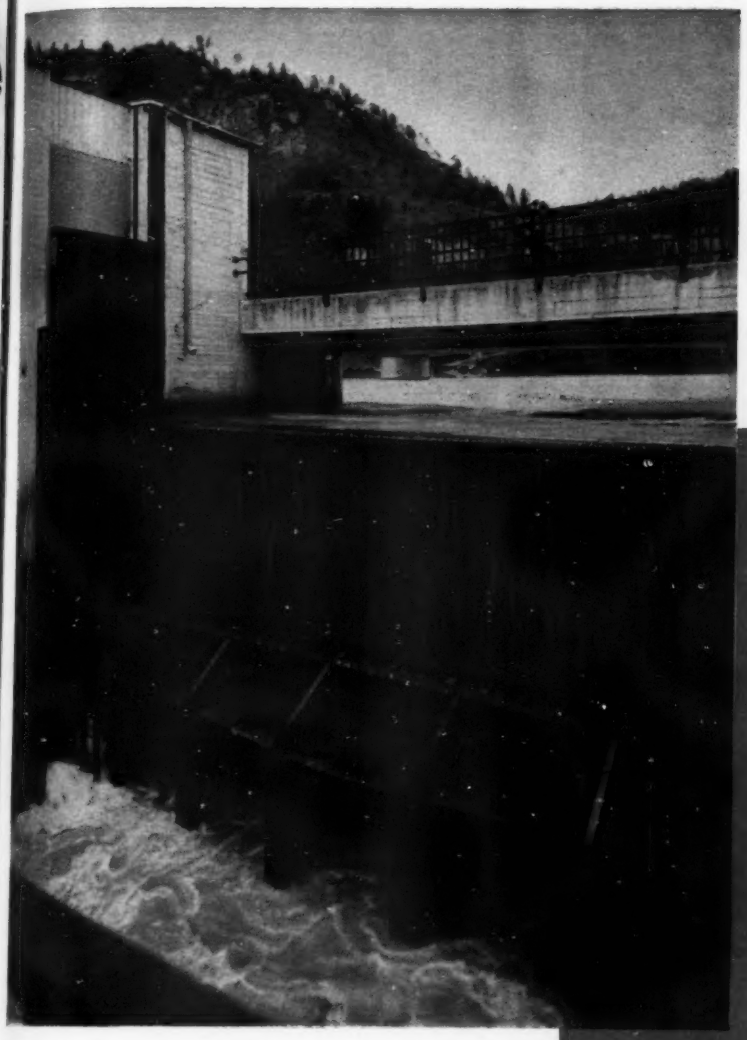
COMPANY _____

STREET _____ CITY _____ STATE _____

SCARPA e MAGNANO

small - oil - volume circuit breakers
metal - enclosed air - insulated switchgear
instrument and protective transformers
isolators
switchboards and control desks

M·A·N



HYDRAULIC STRUCTURES

M·A·N hook-type gates enable, besides fine regulation by lowering the top gate by approx. 40% of the total retaining height, the discharge of average floodwater without operating the bottom gate. Füssen/Lech Weir Plant with 3 M·A·N hook-type gates of 10.5 m clear width and 9.0 m retaining height each.

MASCHINENFABRIK AUGSBURG-NURNBERG AG · GUSTAVSBURG WORKS
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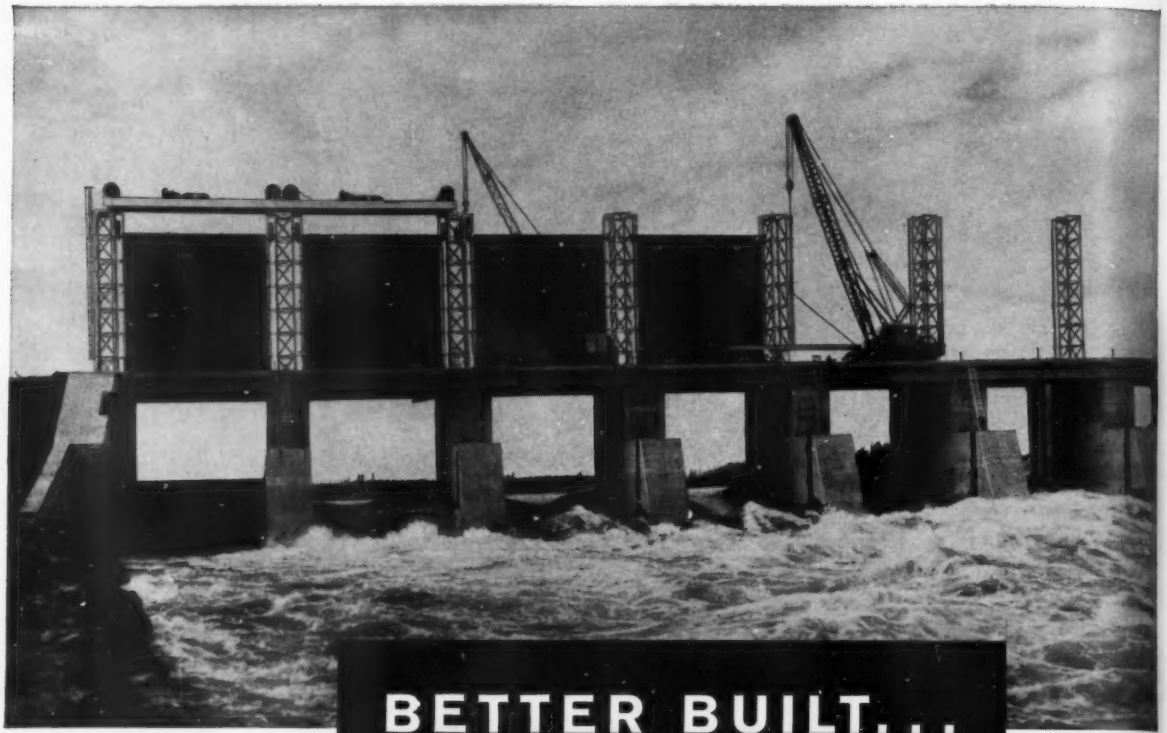

Photo by courtesy of Manitoba Hydro Electric Board.

BETTER BUILT... for better service

Participation in the great Kelsey Generating Station development on the Nelson River was a privilege highly prized by Canadian Vickers. Being entrusted with the manufacturing of nine Sluice Gates with Control Equipment and Embedded Parts bespeaks the confidence placed in the plant facilities, the meticulous engineering and skilled craftsmanship of Canadian Vickers Limited.

CANADIAN VICKERS LIMITED

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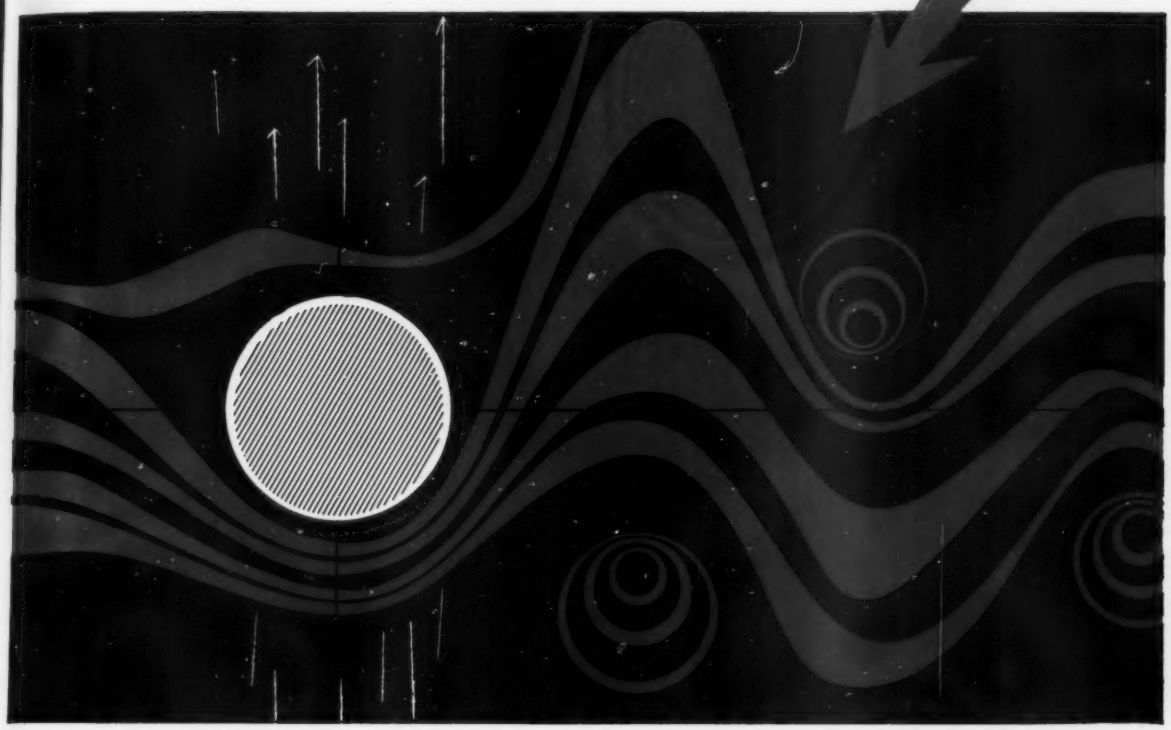
Hydraulic Gates Of All Types • Turbines • Penstocks • Butterfly Valves • Gantry & Power House Cranes • Water Control Equipment Of Every Nature.

Question to Power Line Builders:

Is this your problem?



It could be. The problem of vibrating conductors is still the subject of world-wide investigation. It is a difficult problem because of the many factors involved—climate and the local topography have to be considered, as well as the manner of construction of the power line.

As transmission voltages are raised, too, the problem increases. The large-diameter conductors which are required are more prone to vibrate, since they expose a greater surface to the wind. Having greater tensile strength, they can also be strung more tightly—and higher tension means increased vibration.

The worst vibrations may be caused by very light winds, and in countries where icing is no problem, the regulations may permit undesirably high tensions. Dampers, armour rods, and proper design of the suspension clamps may reduce or eliminate conductor damage resulting from vibration—but in striking a balance between economy and safety, the question is how to determine the most suitable tensioning.

In Sweden vibration problems have been given especial attention, and Svenska Metallverken is now making available the collective know-how which has been acquired on this subject. But whatever your problem, it will pay to consider the advanced technical service which goes with purchases of Feral Cable—*reliable* Swedish ACSR.

NEW TECHNICAL INFORMATION. A special survey of the vibration problem has been prepared for us by a leading expert—an engineer of the Swedish State Power Board who is also chairman of the international committee which is presently studying the matter. Besides incorporating the latest findings, the survey gives recommendations as to suitable practice. Copies of this publication, as well as advice on specific problems, supplied by Swedish experts, can be obtained through Svenska Metallverken, Feral Cable Division.

Vibration Damper of the type generally used in Sweden. Developed by the State Power Board, it acts through loose weights. It is practically unbreakable, relatively cheap, and has no natural frequency which might aggravate conductor vibrations.

When planning power lines, consult

SVENSKA METALLVERKEN

Manufacturers of Feral Cable

FERAL CABLE DIVISION SWEDEN VÄSTERÅS · SWEDEN

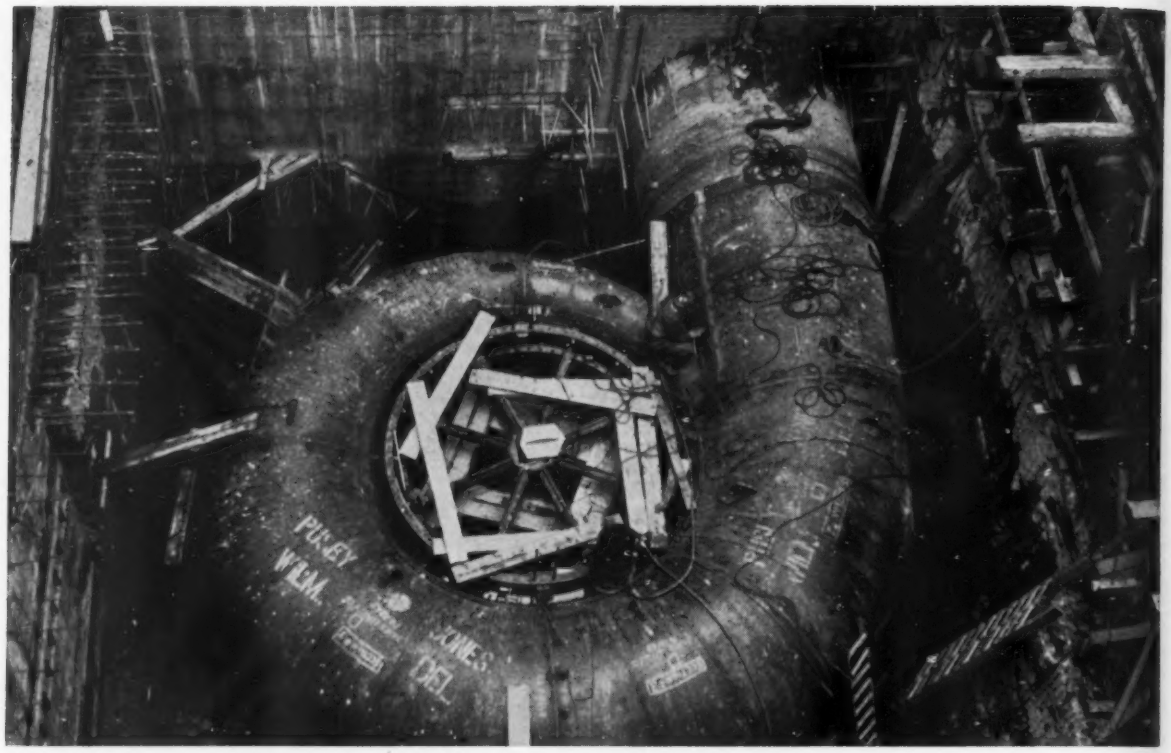


Plate steel spiral scroll case during installation at the Prospect powerhouse.

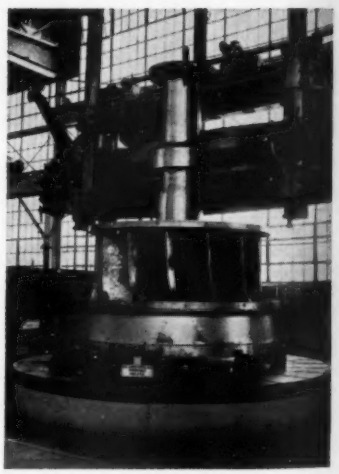
Niagara-Mohawk picks a Leffel Turbine for new Prospect powerhouse

Prospect powerhouse, Niagara-Mohawk's 87th hydroelectric generating plant.

A Leffel spiral case, vertical shaft turbine is the heart of the Prospect Development powerhouse recently completed by the Niagara-Mohawk Power Corporation near Utica, New York. This turbine is rated at 23,900 H.P. at 180 R.P.M. under a 135 foot net head.

Prime factors in Niagara-Mohawk's selection of a Leffel turbine for Prospect were Leffel's long experience in water power development and the proven ability of Leffel turbines to operate at high efficiency year-after-year with absolute reliability.

Take advantage of Leffel's water power know-how on your next project. Nearly a century of experience stands behind every Leffel turbine . . . and this experience is available to you without obligation. Just write, outlining your requirements.



Runner and shaft for the Prospect turbine on Leffel's 24' vertical boring mill.

1112-E

FOUNDED IN 1862

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MORE EFFICIENT HYDRAULIC POWER FOR 98 YEARS

From Pakistan, to Greece or anywhere in the world

COCKBURN-ROCKWELL

BUTTERFLY VALVES

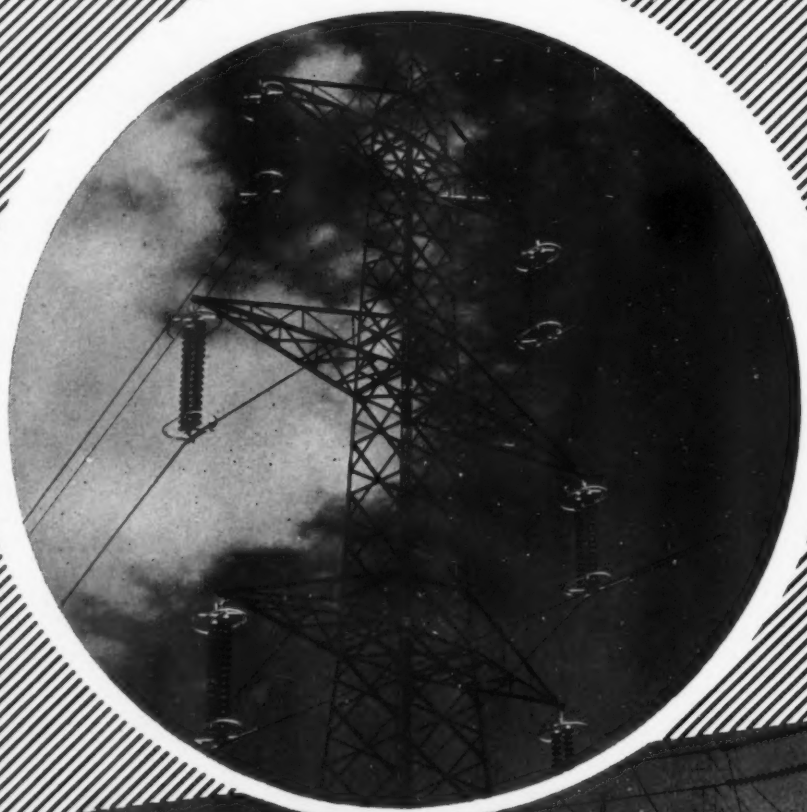
offer a BIG list of advantages

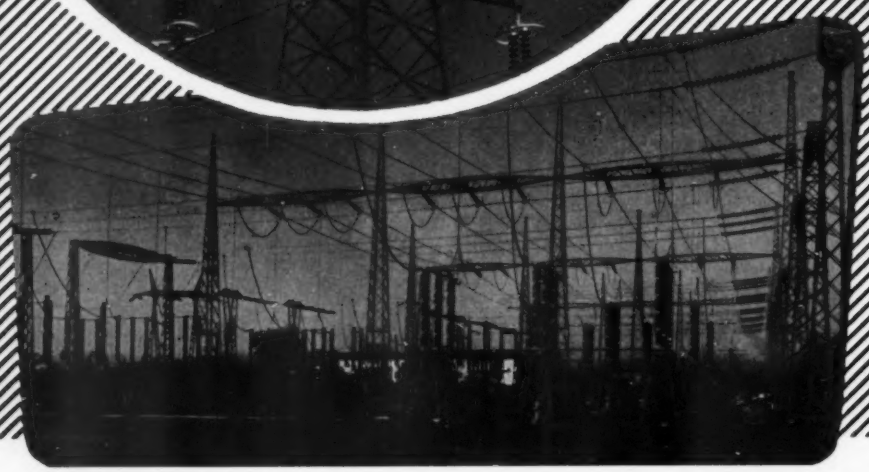
- ★ Leak-tight shut off.
- ★ Great economy in space, compared with gate or globe valves. 2/3 of weight approx.
- ★ No fouling, low pressure drop.
- ★ Easy operation.
- ★ Simple, solid design of body, disc and shaft. Great strength, minimum maintenance.
- ★ International servicing available.

Thirty-six COCKBURN-ROCKWELL Butterfly Valves in sizes up to 72″ diameter were recently supplied on a Pakistan Power Station Contract. A further thirty valves, 48″ to 72″ diameter, are now being installed in the Athens Water System extension.

COCKBURNS LTD Cardonald Glasgow SW1

SALVI





For 30 years Messrs. A. Salvi and Company, Milano, Italy, have specialized in the design and manufacture of complete equipment for Overhead Transmission Lines, including Compression Dead End Assemblies and Joints. The Works of the Salvi Company are engaged exclusively in the production of high grade fittings for High Voltage Transmission Systems, up to and including voltages of 220/380 KV and for all sizes of Copper, A.C.S.R. and Aluminium Alloy Conductors.

SOLE REPRESENTATIVES IN THE UNITED KINGDOM AND THROUGHOUT ALL DOMINION COUNTRIES (EXCEPT AUSTRALIA AND NEW ZEALAND) AND BRITISH COLONIES AND PROTECTORATES

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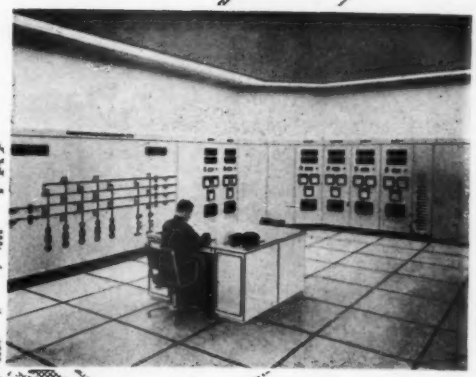
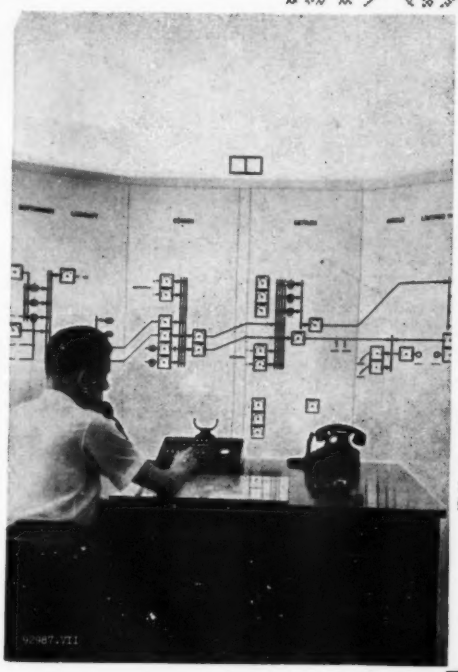
BROWN BOVERI



TELECOMMUNICATION



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are an ideal means of communication for electricity undertakings.

All over the world they are in use with telephone, teleprinter, telemetering and regulation systems; also transmitting signals for the remote control of sub-stations and generating plant, and for intertripping schemes using high-speed distance protection relays.

Representatives in most countries

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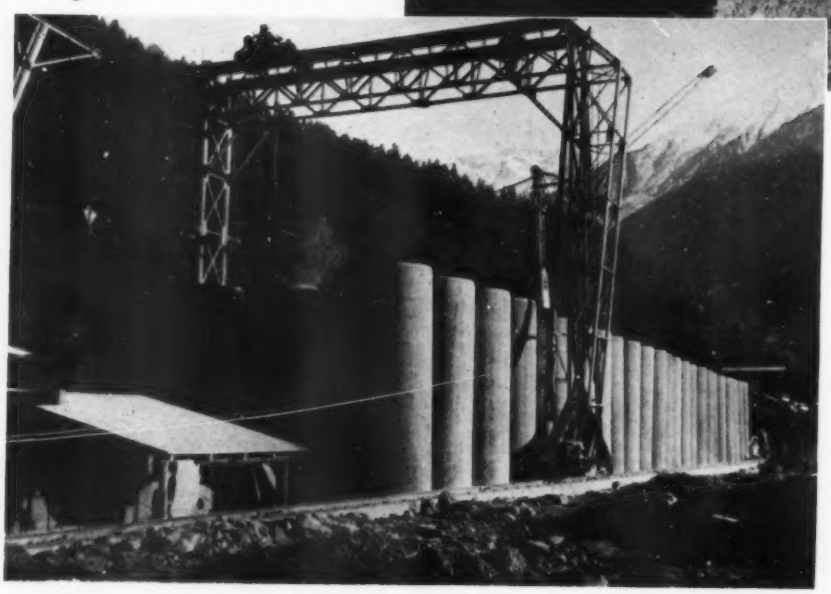
Reinforced Concrete Pipes, ordinary and pre-stressed, in all diameters and pressures, for Hydro-Electric Plants and Aqueducts



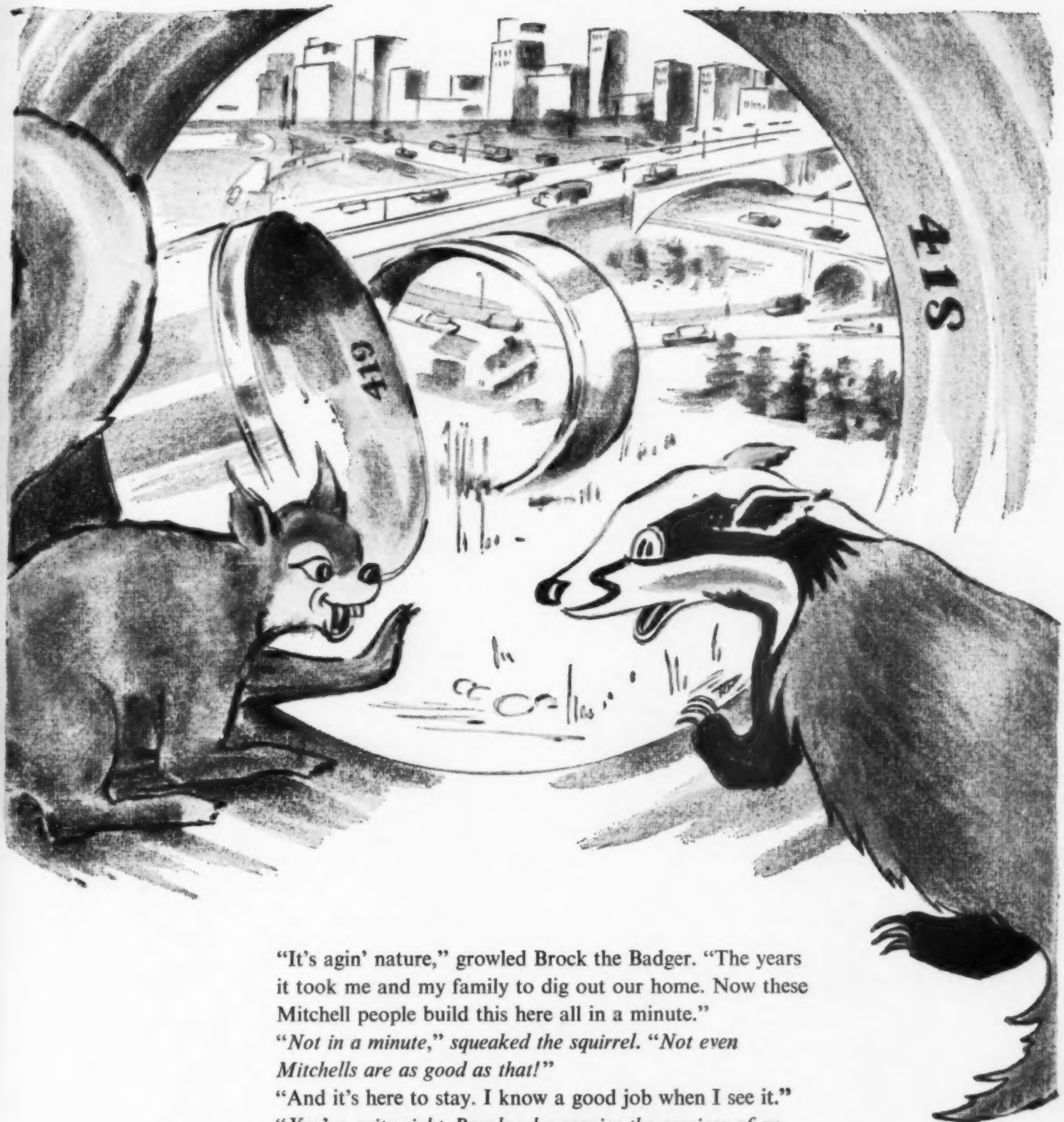
TIWAG

PENSTOCK AT PITZBACH (AUSTRIA) in pre-stressed reinforced concrete, constructed in collaboration with ALFRED KUNZ & CO. of Bludenz

SACAIM

Soc. p. Az. Cementi Armati Ing. Mantelli

VENICE (ITALY) - Accademia 979/A - Telephone 85·060



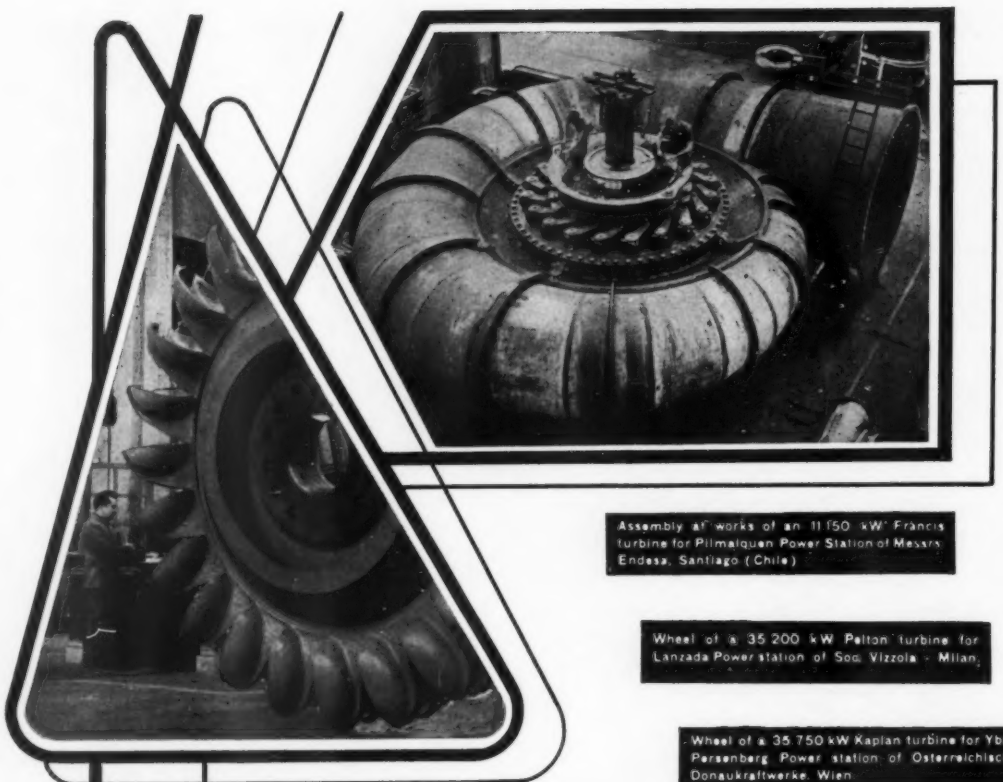
"It's agin' nature," growled Brock the Badger. "The years it took me and my family to dig out our home. Now these Mitchell people build this here all in a minute."
"Not in a minute," squeaked the squirrel. "Not even Mitchells are as good as that!"
"And it's here to stay. I know a good job when I see it."
"You're quite right. People who require the services of an experienced firm of building and civil engineering contractors ought to get in touch with Mitchell Construction."

MITCHELL CONSTRUCTION

BUILDING & CIVIL ENGINEERING CONTRACTORS
THE MITCHELL CONSTRUCTION COMPANY LTD
WHARF WORKS · PETERBOROUGH

P.4017

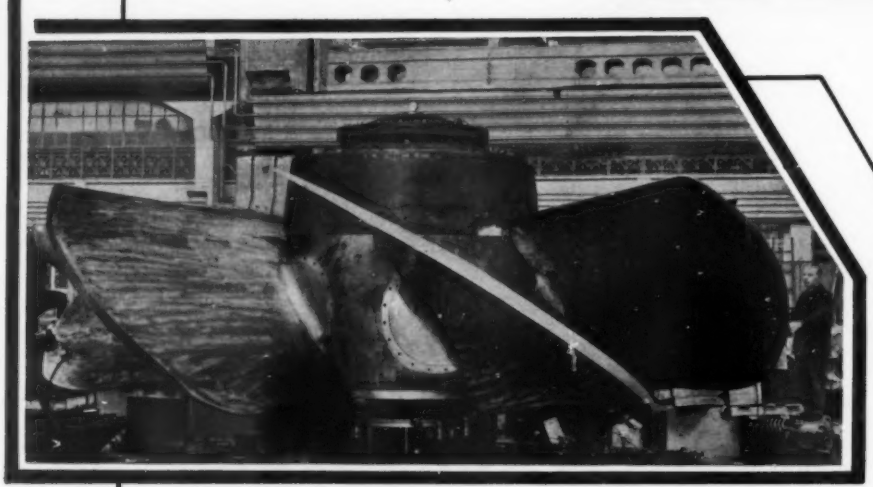
Complete hydro-electric plants



Assembly at works of an 11 150 kW Francis turbine for Pilmaiquen Power Station of Messrs Endesa, Santiago (Chile)

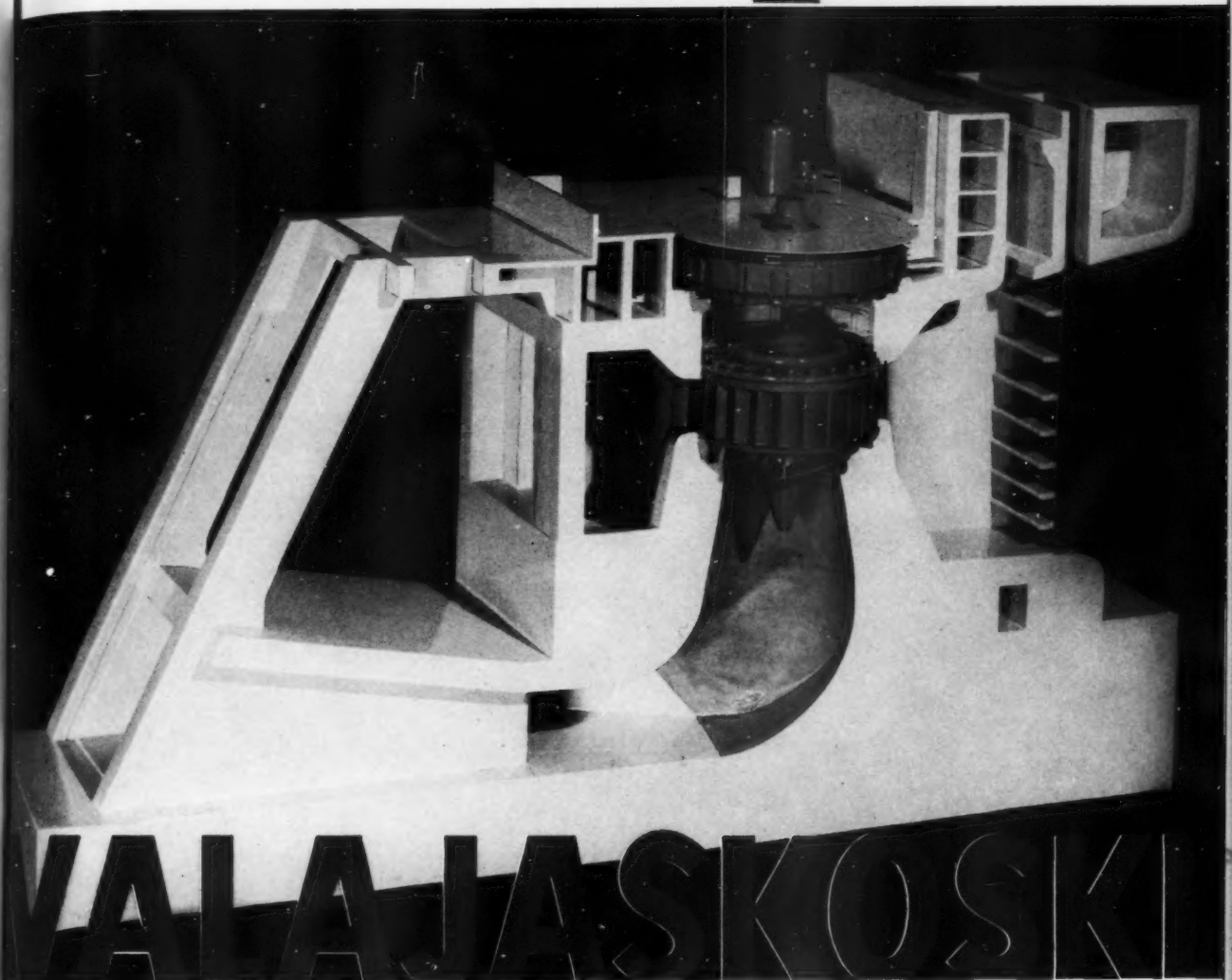
Wheel of a 35 200 kW Pelton turbine for Lanzada Power station of Soc. Vizzola - Milan.

Wheel of a 35 750 kW Kaplan turbine for Ybbs Persenberg Power station of Osterreichische Donaukraftwerke, Wien.



ANSALDO-SAN GIORGIO
GENOVA

Finland's largest turbine



Miniature model of the Valajaskoski turbine and its concrete construction.

The outer periphery of the runner blades is being turned. The runner diameter 6250 mm. is hitherto the largest in Finland.

Valajaskoski, one of the power plants in the biggest river of Finland, the Kemi River, is now being completed. For this plant, 2 Kaplan-turbines have been delivered by Tampella, each with the following technical data:—

H = 11·2 m. Q = 250 cu. m./sec.
N = 33·900 h.p. n = 75 r.p.m.

Tampella

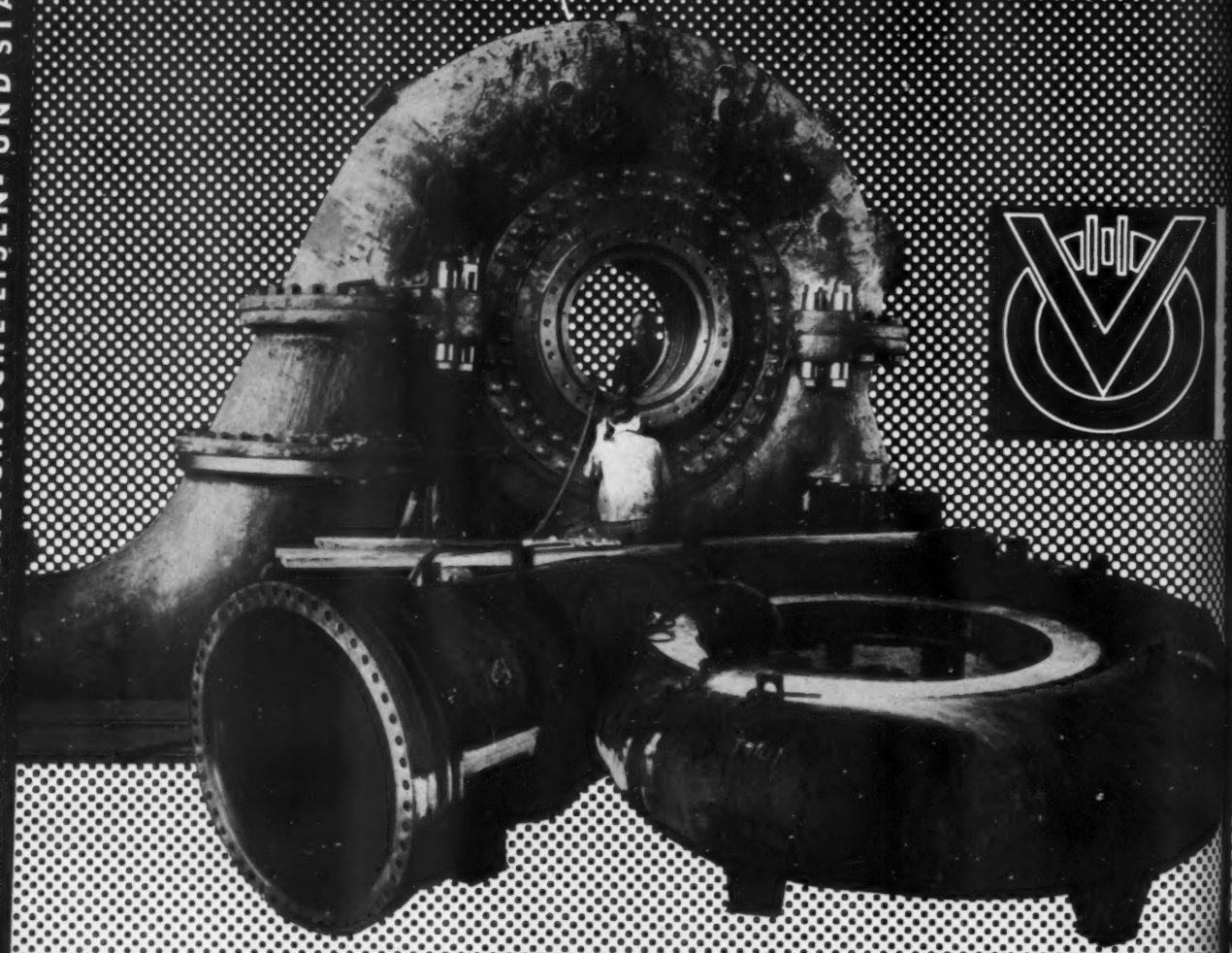
TAMPELLA ENGINEERING WORKS
TAMMERFORS · FINLAND
Established 1842

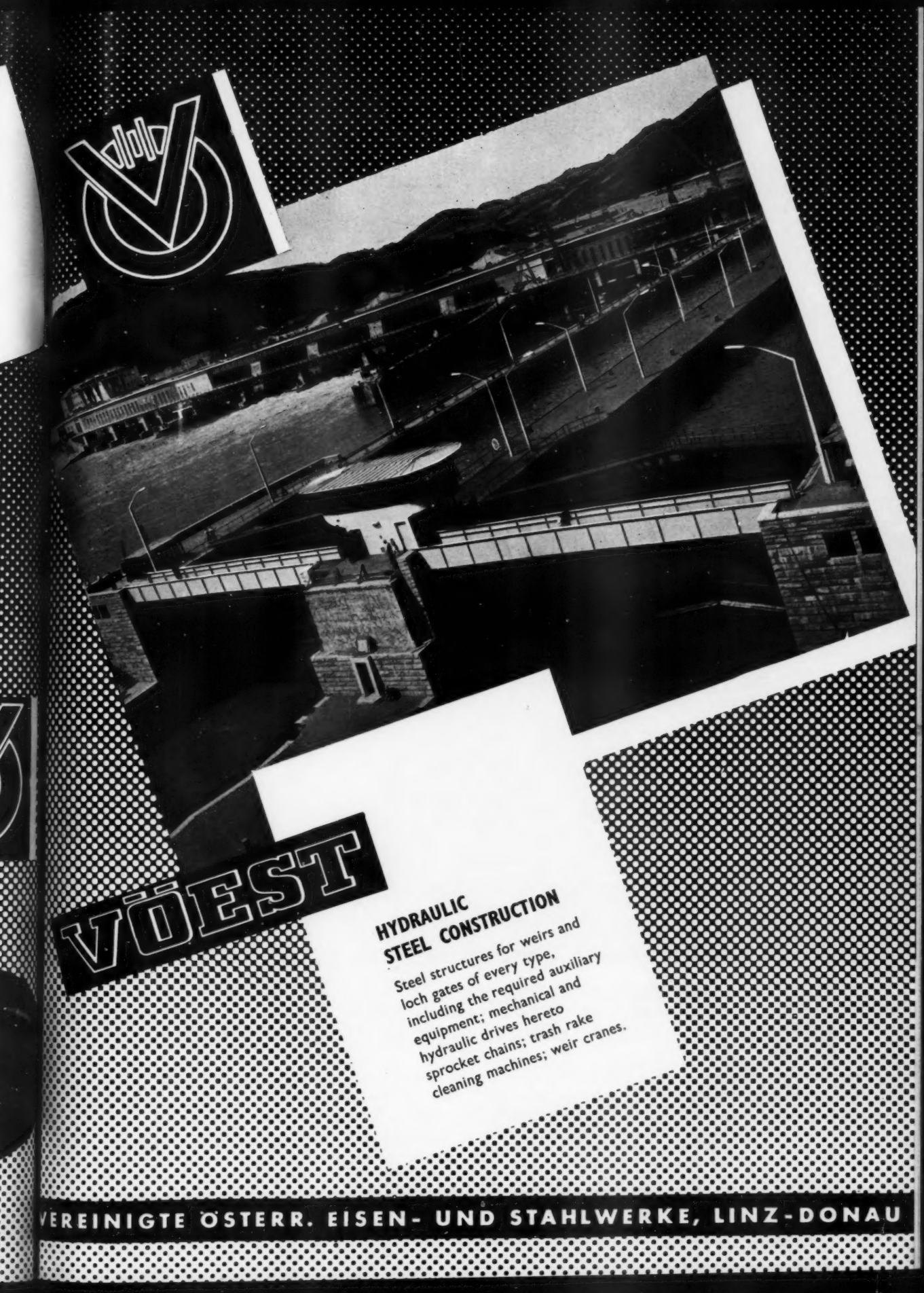
VÖEST

VEREINIGTE ÖSTERREICHISCHE EISEN- UND STAHLWERKE, LINZ-DONAU, AUSTRIA

Hydraulic Turbines, Spherical and Butterfly Valves

Licensed by Baldwin-Lima-Hamilton Corp.
Philadelphia, U.S.A.




VÖEST
HYDRAULIC
STEEL CONSTRUCTION
Steel structures for weirs and
loch gates of every type,
including the required auxiliary
equipment; mechanical and
hydraulic drives hereto
sprocket chains; trash rake
cleaning machines; weir cranes.
VEREINIGTE ÖSTERR. EISEN- UND STAHLWERKE, LINZ-DONAU

Controlled feed · guided collaring · mechanical retraction— so one man can operate two rigs

NORTHERN SWEDEN has been the proving ground of a revolutionary rock drilling method which has opened the way to a completely new conception of drill-crew output. Known as the Swedish Ladder Drilling Method, this new technique has been employed on hydro-electric projects at Korsselbränna and Stalon where drilling platforms with 16 rock drills operated by 8-man drill crews have been used.

Atlas Copco drills mounted on retractable pusher legs* are rested in cradles running horizontally in "ladders". Contractors and drill crews have found that these rigs, cheaply and simply constructed, offer the following advantages:

INCREASED PENETRATION—full feed power is ensured by the ideal horizontal feeding position of the pusher leg.

HIGHER OUTPUT PER MAN/HOUR—due to greater penetration and the fact that *one man handles two drills.*

REDUCED CREW FATIGUE—collaring is made simple as operators need not hold the drills. Drill steels are mechanically withdrawn from holes using the retractable pusher leg.

FEWER DRILL STEEL CHANGES—long steels can be used from the start. For greater durability 1″ Sandvik Coromant integral steels are used.

GREATER DRILLING ACCURACY—thanks to the fixed ladder base and pre-positioning of drills for pattern drilling.

DRAMATIC RESULTS OF LADDER DRILL TESTS

The figures show the dramatic increase in drilling achieved by ladder rigs in a 60 sq.m. tunnel at Stalon driven in hard-drilled quartzite. Gross effect refers to the mean value for the whole drilling period, including collaring, changing steels and the usual routine delays. *Note that the gross effect is exactly doubled.*

GROSS EFFECTS

19.5 metres/man-hour Conventional drilling with one rock drill

39.0 metres/man-hour Ladder drilling with two drills

AVAILABLE FROM ATLAS COPCO

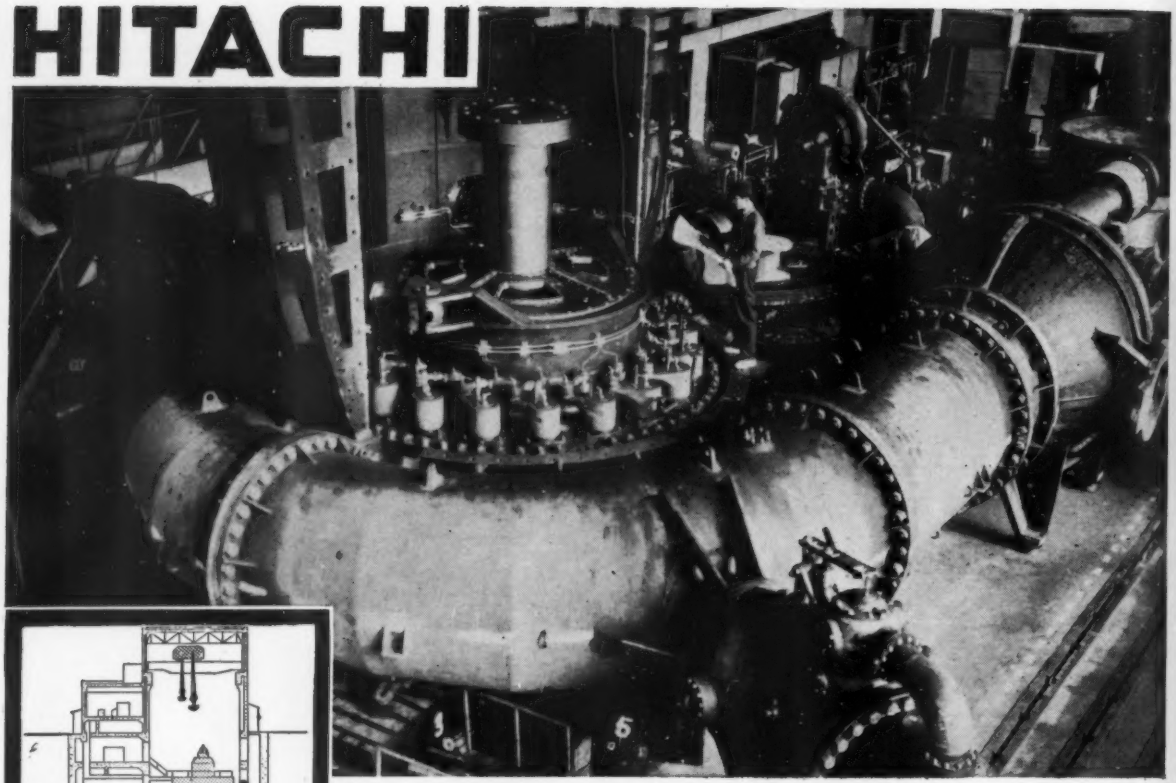
The Swedish Ladder Drilling Method was originally introduced by Widmark and Platzer, one of Sweden's leading contracting companies, and has been further developed by them and by the Swedish State Power Board. Specially evolved with Atlas Copco trigger-operated retractable pusher legs*, this method and equipment has been exhaustively tested and proved under tough Swedish drilling conditions. There are Atlas Copco companies or agents in ninety countries and details of the new equipment are readily available from them or from the address below. Wherever you are, the international Atlas Copco group offers expert advice on the selection of equipment and a complete after-sales service.

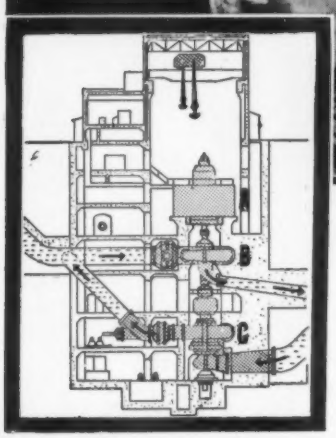
* PATENTS PENDING

Atlas Copco

PUTS COMPRESSED AIR TO WORK FOR THE WORLD
ATLAS COPCO AB, STOCKHOLM 1, SWEDEN.

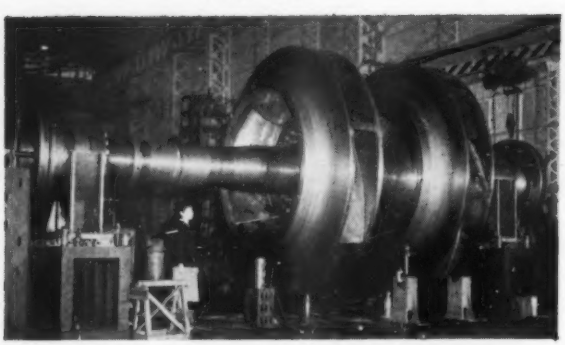
HITACHI





A Generator-Motor
B Turbine
C Pump

▼ Pump Impeller



Pump and Turbine Completed for the Huge Pumped Storage Power Station

Hitachi, Ltd. has recently completed a mammoth vertical shaft 56,500 kW turbine pump for delivery to the Morozuka Pumped Storage Power Station in Japan to surpass world level in this field. This turbine pump is scheduled to be installed with a 58,000 kVA/56,500 kW generator-motor and a 53,000 kW turbine, also of the Hitachi make.

This pump is to be operated on surplus power when it becomes available on such occasions as rainy seasons or midnight operations for pumping up water to the reservoir. The water stored this way is used to increase power output of the station in the peak-load period.

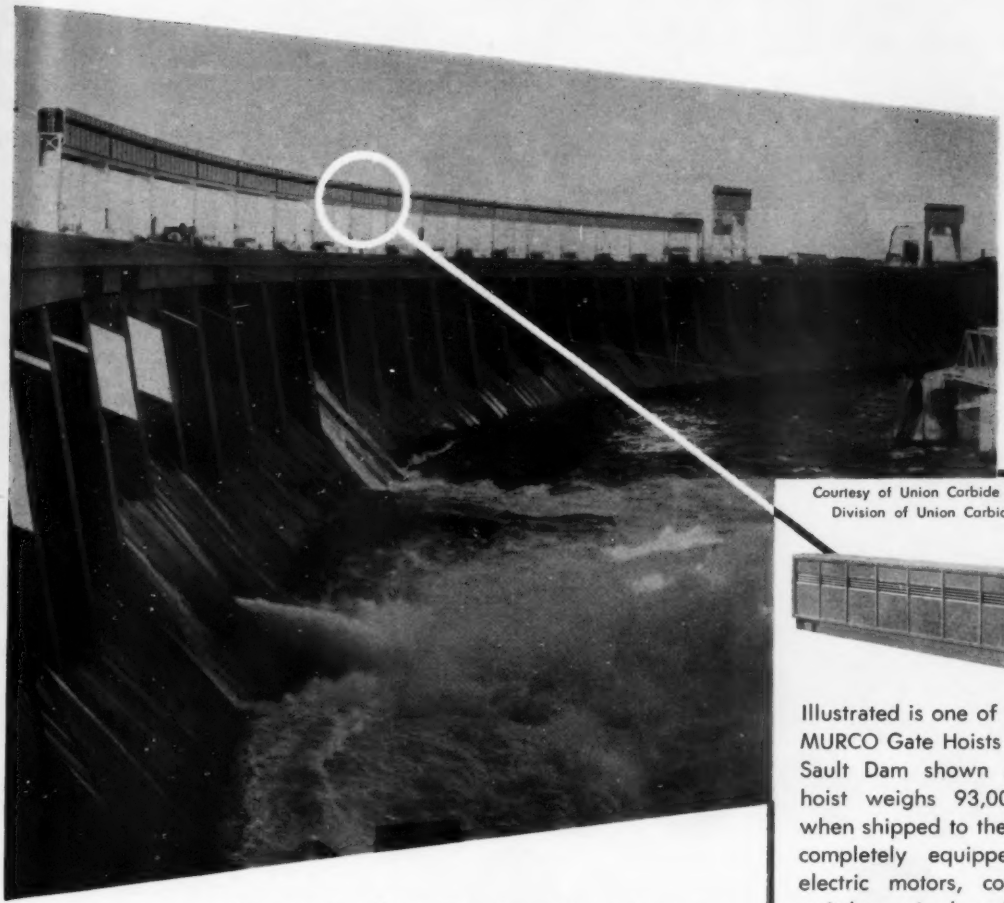
Hitachi, Ltd.
Tokyo Japan
Cable Address: "HITACHY" TOKYO

The Specifications of the various parts are as follows:

Pump	Quantity	18.6 m³/s
	Total Head	241.4 m
	Speed	300 rpm
Turbine	Effective Head	222 m
	Output	53,000 kW
	Speed	300 rpm

Generator-Motor	Output	58,000 kVA (Generator) 56,500 kW (Motor)
	Voltage	11,000 V
	Current	3,045 A
	Frequency	60 cycles
	Speed	300 rpm

Beside the above, Hitachi, Ltd. also made and delivered automatic operational control equipment, transformers, switchboards, A.C. circuit breakers, overhead travelling cranes and other equipment for the Morozuka Power Station.



Courtesy of Union Carbide Plastics Company
Division of Union Carbide Corporation.

Illustrated is one of the eighteen MURCO Gate Hoists on the Long Sault Dam shown above. Each hoist weighs 93,000 lbs. and when shipped to the project was completely equipped with all electric motors, controls, limit switches, wired ready for operation when installed.

Each MURCO Gate Hoist, as illustrated, has 175 tons lifting capacity . . . will raise and lower the gates in the dam at a speed of 1 foot per minute.

The overall length of each unit is 57 feet . . . 8½ feet wide and 12½ feet high.

Write for complete information . . . Engineering Department recommendations . . . when you are planning power dam projects.

. . . to control water level at Long Sault Dam, St. Lawrence Power Project

MURCO GATE HOISTS

For the second largest hydroelectric power plant in the United States at Massena, New York -- as part of the St. Lawrence power project -- Uhl, Hall & Rich, project engineers, selected MURCO Gate Hoists to control the water level at Long Sault Dam.

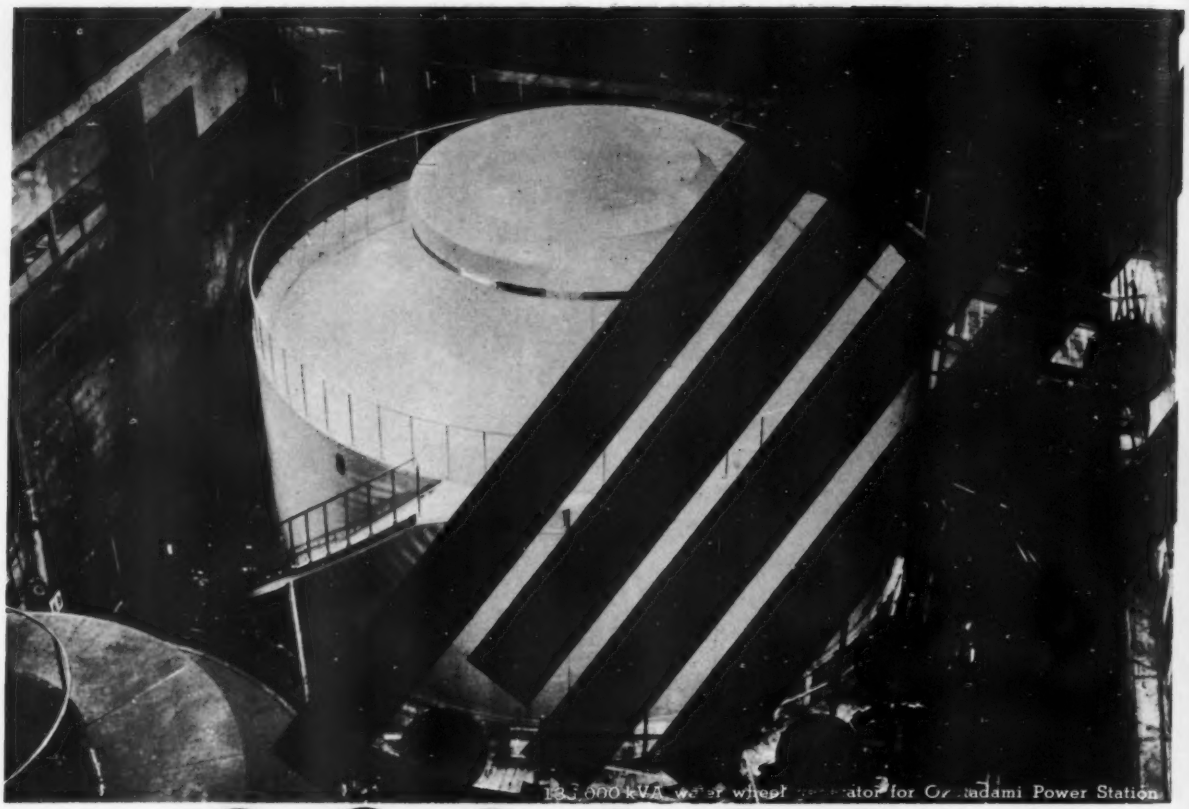
MURCO Gate Hoists are designed from knowledge and experience . . . backed by over 75 years in design and manufacture . . . with hundreds of successful installations made for leading engineers, power companies, industrial plants, government power projects . . . each MURCO Gate Hoist designed to do its job, incorporated into its design the factors that meet the requirements of the operators.

MURCO Gate Hoists are designed and made for any size power dam . . . capacities from less than 1 ton to over 100 tons . . . from the smallest hand operated to the largest motor operated gate hoist, all made to specifications.

Manufacturers Since 1883

D. J. MURRAY MANUFACTURING CO.

WAUSAU, WISCONSIN, U.S.A.



133,000 kVA water wheel generator for Okutadami Power Station

Toshiba

Contributing to Your Better Living!

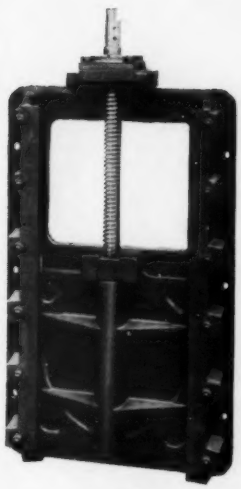
Heavy electric equipment for domestic and overseas use is being sent out one after another from Toshiba's Tsurumi Works.
Shown here (right) is one of the 3 scheduled 133,000 kVA generators—the second largest in the world—to be installed at Okutadami Power Station in central Japan.
You can also see part of the 58,000kVA generator at the corner of the picture, which is now in operation at Mazatepec Power Station in Mexico.
And...Toshiba is working on the next one.

TOKYO SHIBAURA ELECTRIC CO., LTD.

2, Ginza Nishi 5-chome, Chuo-ku, Tokyo, Japan. Cable: TOSHIBA TOKYO

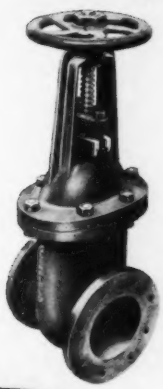
GLENFIELD EQUIPMENT

for Ancillary Networks



Besides large gates, valves and other equipment for the main parts of hydro-electric projects, Glenfield products cater for all requirements for aqueducts, subsidiary pipelines, pumping stations, domestic water supplies and fire fighting systems.

Only a few examples are illustrated covering single-faced Sluices, hand-operated Sluice Valves, Air Valves, Check Valves, Fire Hydrants and Pressure Reducing Valves.

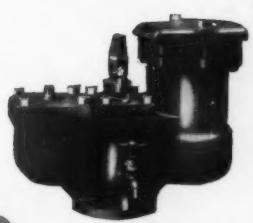


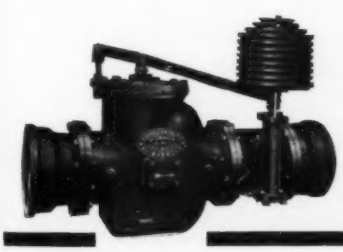
Glenfield

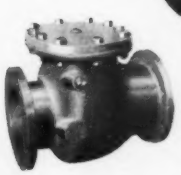
GLENFIELD & KENNEDY LIMITED KILMARNOCK

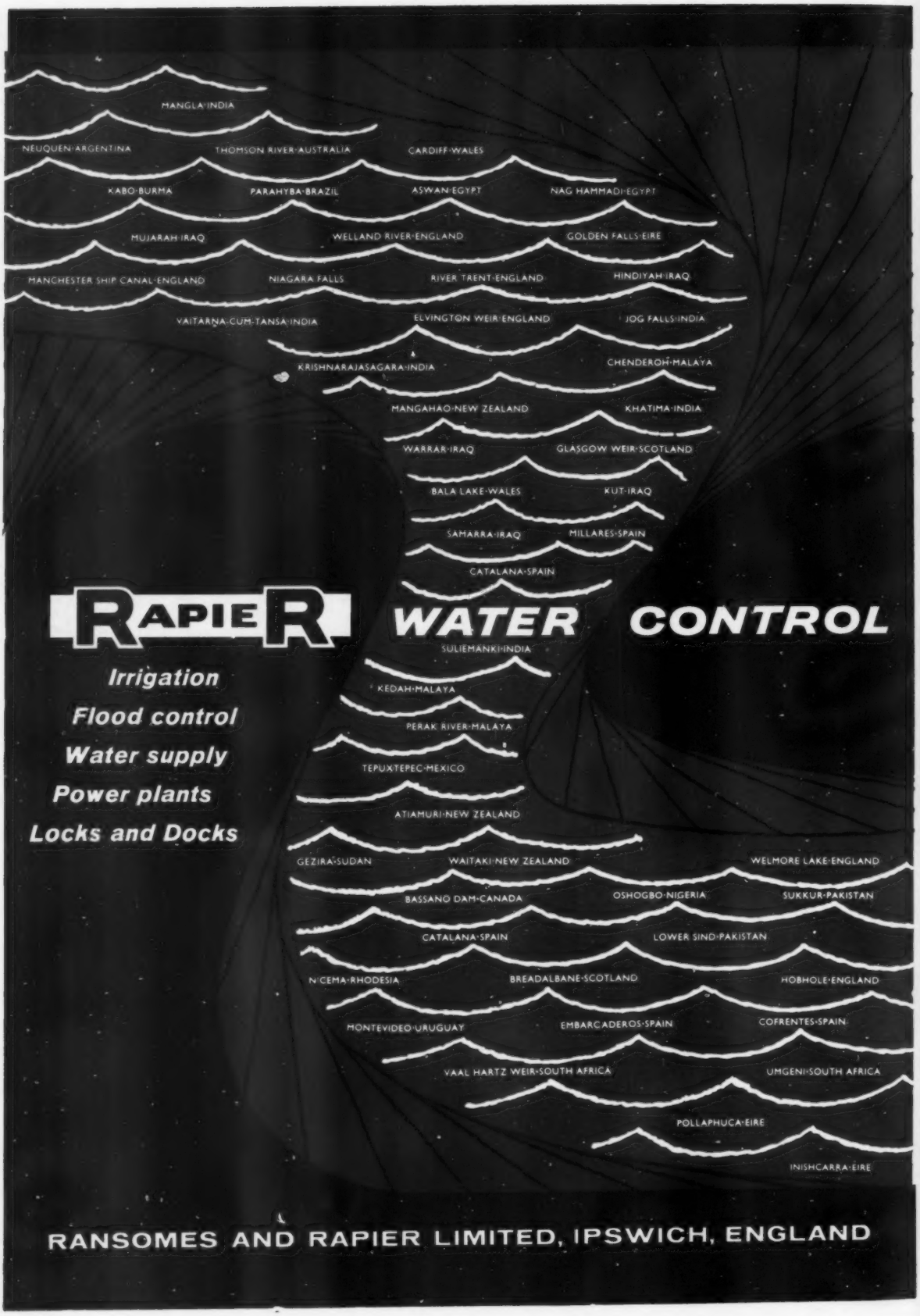
Head Office and Works:

KILMARNOCK · SCOTLAND








MANGLA·INDIA
NEUQUEN·ARGENTINA
THOMSON RIVER·AUSTRALIA
CARDIFF·WALES
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PARAHYBA·BRAZIL
ASWAN·EGYPT
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WELLAND RIVER·ENGLAND
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SAMARRA·IRAQ
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KEDAH·MALAYA
PERAK RIVER·MALAYA
TEPUXTEPEC·MEXICO
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RANSOMES AND RAPIER LIMITED, IPSWICH, ENGLAND

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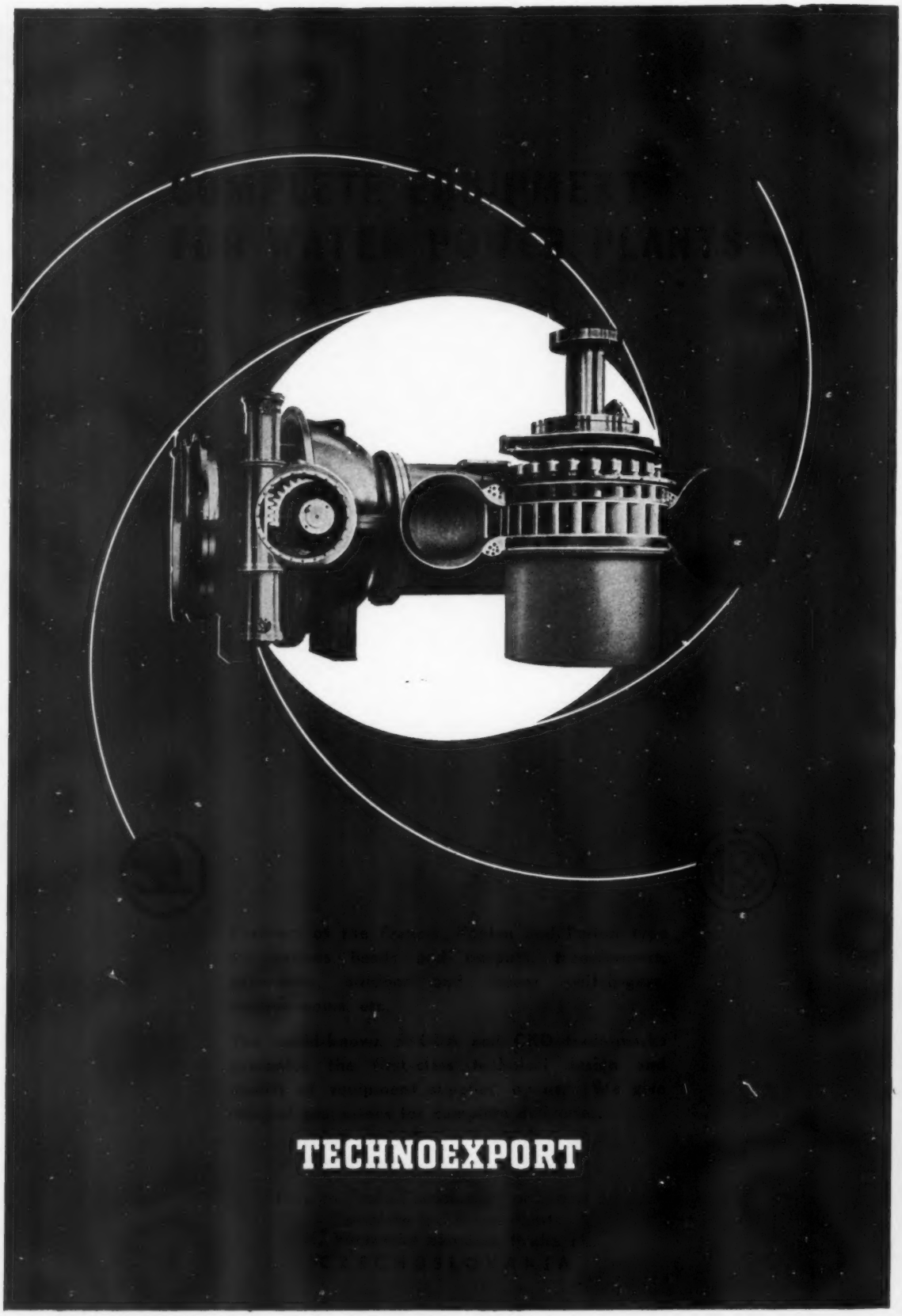
105,000 kVA Water-wheel Generator

The comforts of life are the assured gifts of electric power . . .
Mitsubishi Electric engineers, workers . . . all perform their important tasks in making life comfortable . . . they help in the manufacture of every type of electrical equipment from giant generators and transformers to small home appliances that make life easier. For matchless experience and a distinguished history of achievement, look to the three DIAMONDS of the Mitsubishi Brand . . . the symbol of QUALITY and INTEGRITY.

MITSUBISHI ELECTRIC MANUFACTURING COMPANY

Head Office: Tokyo Building, Marunouchi, Tokyo Cable Address: MELCO TOKYO



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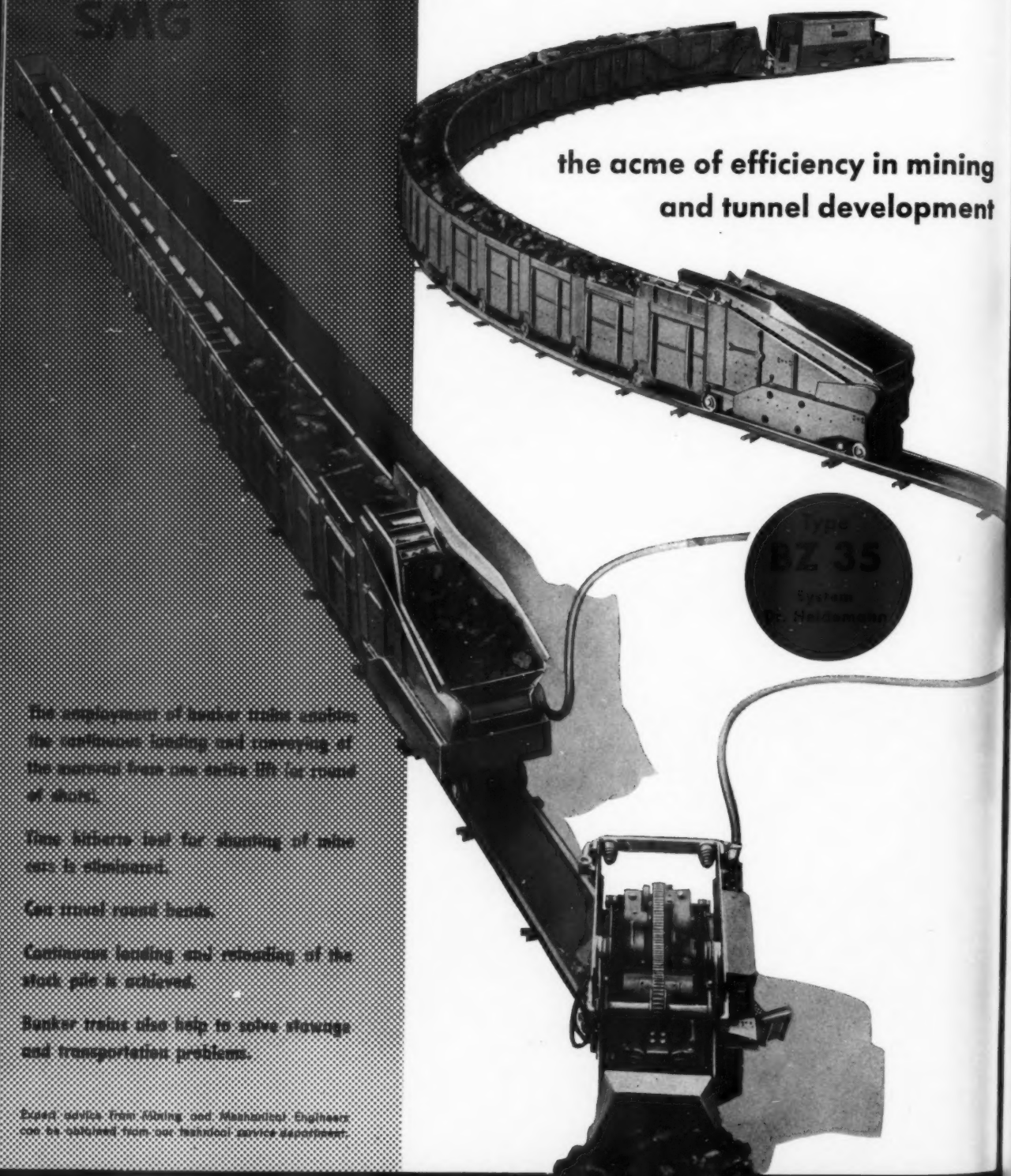
We design
manufacture and erect

PENSTOCKS

SALZGITTER BUNKER TRAIN

the acme of efficiency in mining and tunnel development



The employment of bunker trains enables the continuous loading and conveying of the material from one centre lift to round of shots.

Time hitherto lost for shunting of mine cars is eliminated.

Cars travel round bends.

Continuous loading and reloading of the stock pile is achieved.

Bunker trains also help to solve stowage and transportation problems.

Expert advice from Mining and Mechanical Engineers can be obtained from our technical service department.

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SALZGITTER-BAD (W. Germany)

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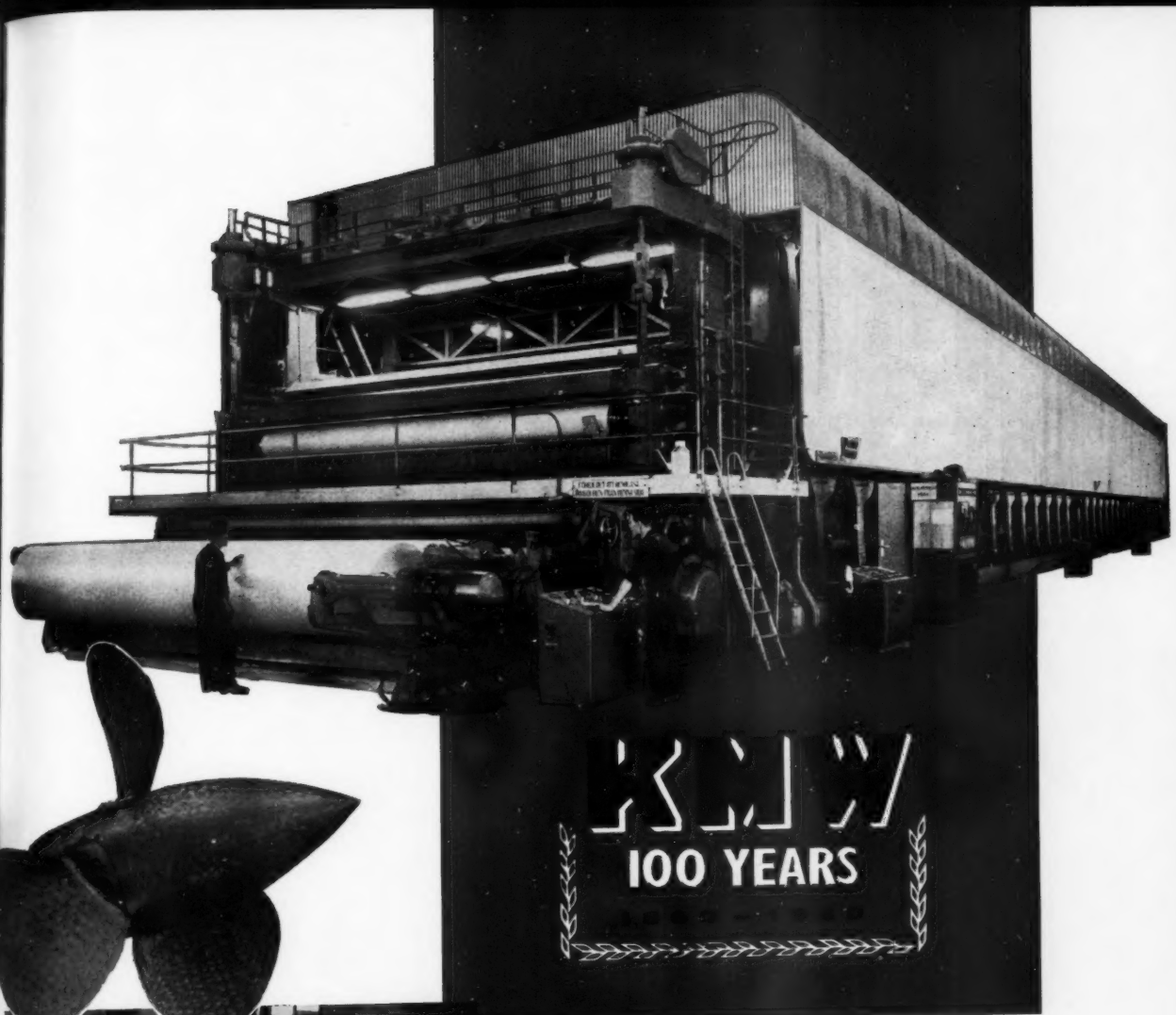
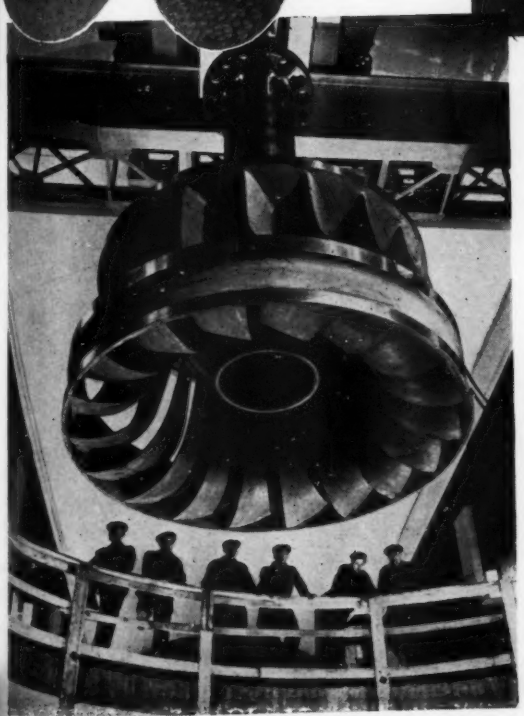




This year AB Karlstads Mekaniska Werkstad—a Swedish heavy industry with world-wide fame—enter into a new century of activity. In 1860 a small machine-shop and foundry were established on the site of the present works at Karlstad. The firm attained its present status in 1873, and in the late seventies KMW began to manufacture the products which later made the firm's name known the world over, i.e., machinery for the pulp and paper industries.

Development proceeded rapidly, and in 1897 Kristinehamns Mekaniska Werkstad was purchased by KMW. The manufacture of water turbines was subsequently concentrated at Kristinehamn, and these products also became well-known all over the world. The third main branch of manufacture was developed in 1936 when KMW started to make controllable-pitch KaMeWa propellers, now delivered to a wide variety of ships of many nations.

The 100th anniversary celebration will include the completion of a new plate shop and a large new research laboratory for further development of KMW paper machines. For their other main products, water turbines and propellers, KMW have modern laboratories which are among the best equipped in the world.

KMW is well equipped to meet a new century.

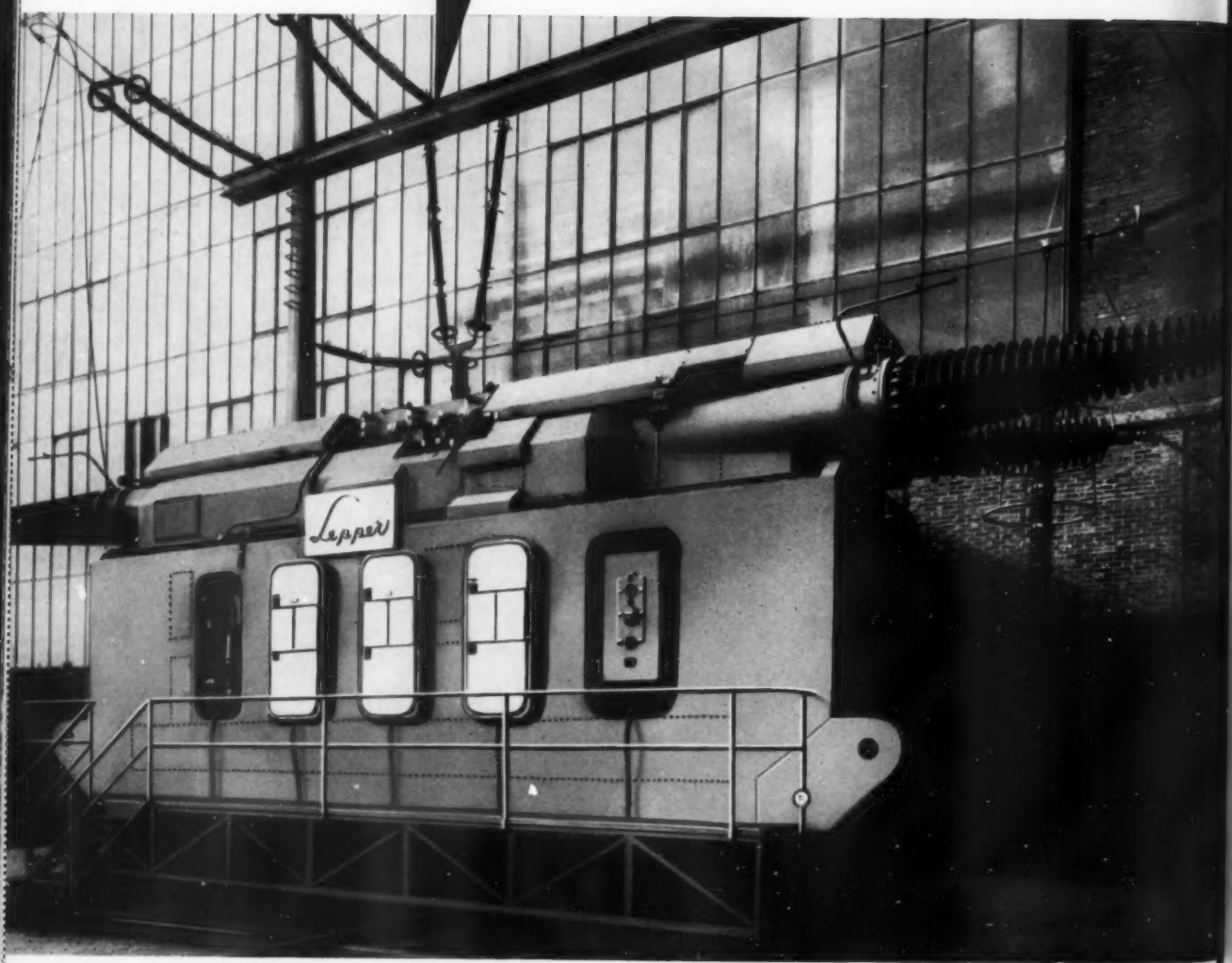
AB KARLSTADS MEKANISKA WERKSTAD

KARLSTAD • SWEDEN

90 MVA transformer with built-in tap changing gear, 245 ± 9 × 3·03/10·5 kV mobile with ON/OFF cooling.

Lepper

Transformers



Transformatorenwerk
August Lepper, Honnef/Rhein
West Germany

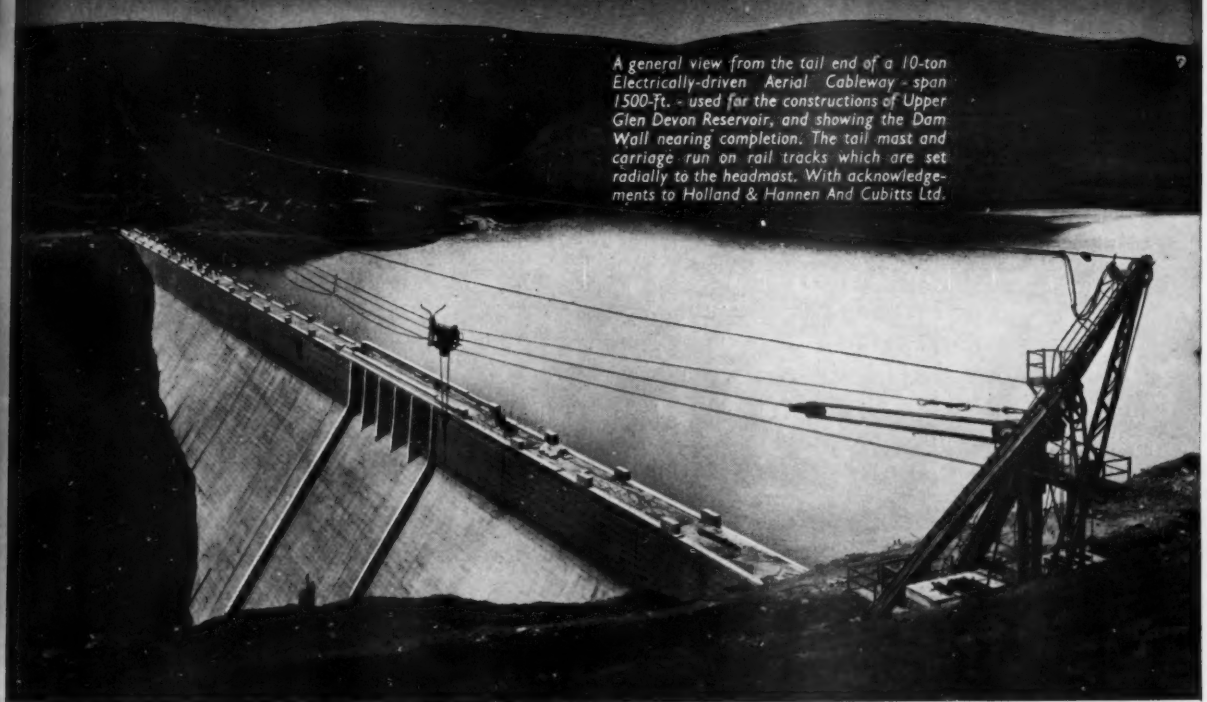
well on top of schedule

MOVEMENT of materials . . . . . that's the secret of meeting schedules on great projects. Getting the stuff in, putting the machinery on the job, - half the battle is won when movement is unhampered, when the equipment which handles the gear does so with unfailing reliability.

Henderson Cableways fit the description. Not only is each component built to the highest degree of engineering skill - Henderson Cableways are undoubtedly the most economical method of moving big loads on the majority of dam, barrage, bridge or viaduct contracts. Confirmation of this fact lies in the considerable number of cableways we have installed at vast projects throughout the world.

Henderson *CABLEWAYS*

lifelines to movement



A general view from the tail end of a 10-ton Electrically-driven Aerial Cableway - span 1500-ft. - used for the constructions of Upper Glen Devon Reservoir, and showing the Dam Wall nearing completion. The tail mast and carriage run on rail tracks which are set radially to the headmast. With acknowledgements to Holland & Hannen And Cubitts Ltd.

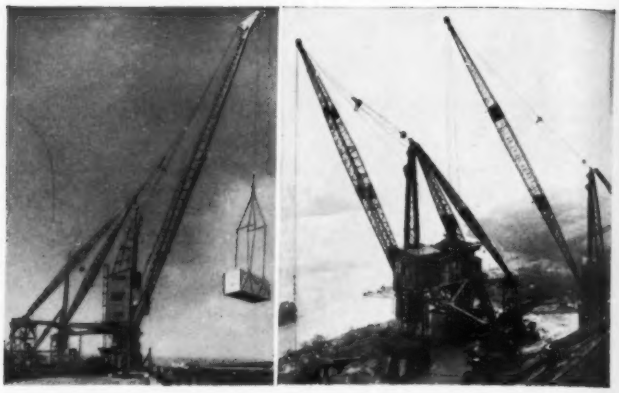
JOHN M HENDERSON AND CO LIMITED KINGS WORKS ABERDEEN

COSTS

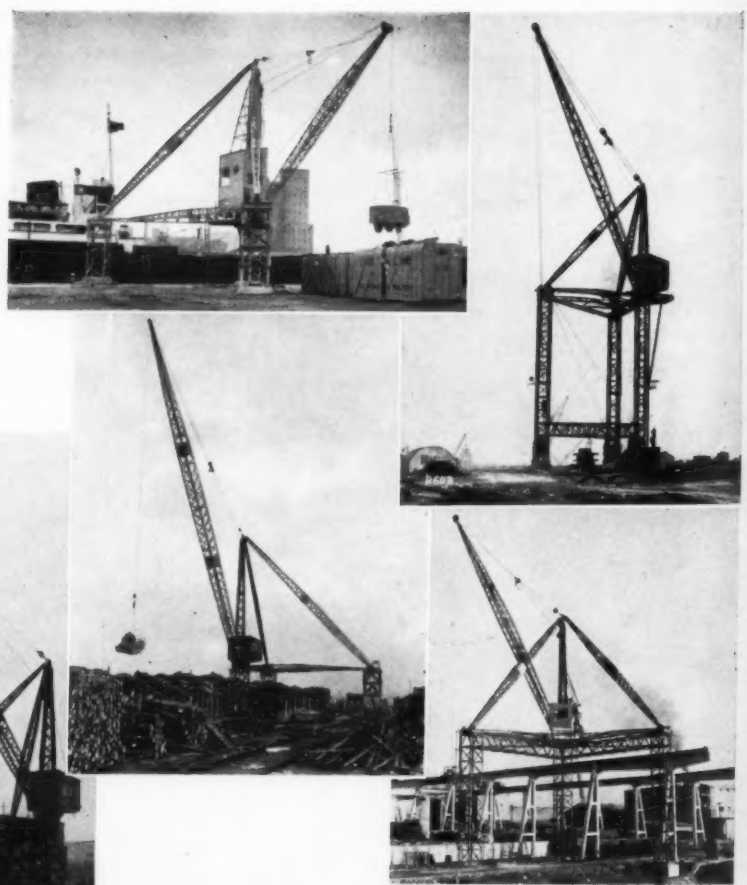
COME DOWN

WITH

BUTTERS DERRICKS



- low first cost
- lower maintenance costs
- lower cost of operation
- minimum maintenance
- simplicity, reliability and high efficiency



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FOR HARD SERVICE AND LONG LIFE THE BUTTERS DERRICK IS UNSURPASSED

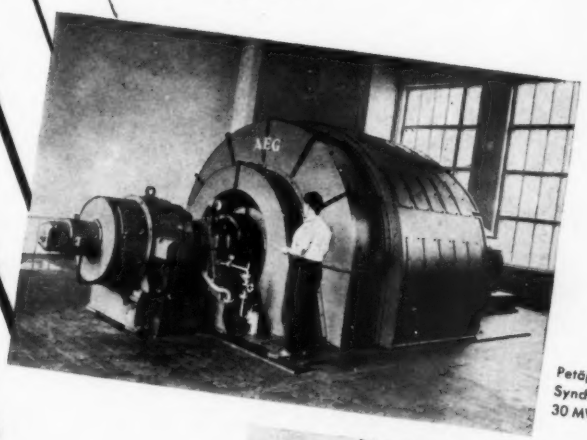
AEG

SYNCHRONOUS CONDENSERS

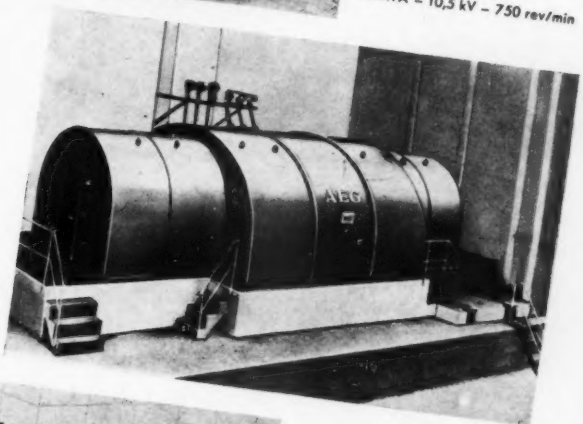
Economical operation of large grids and other distribution systems call for a compensation of the reactive component, i.e., improvement of the power factor.

Large synchronous condensers will best suit the purpose also under conditions of heavy line voltage fluctuations.

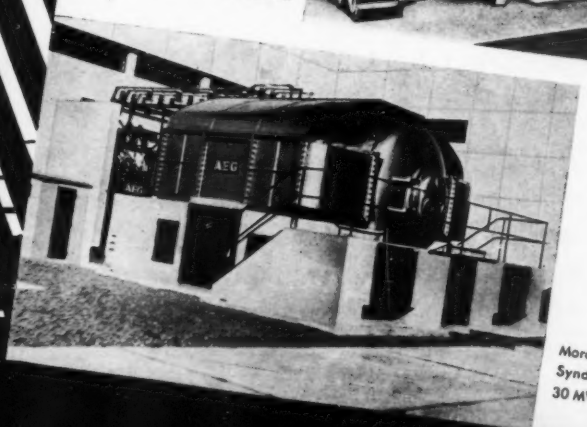
The AEG manufacturing programme covers all sizes of synchronous condensers for supply systems as well as for industrial application.



Petäjevesi, Finland
Synchronous Condenser
30 MVA – 10,5 kV – 750 rev/min



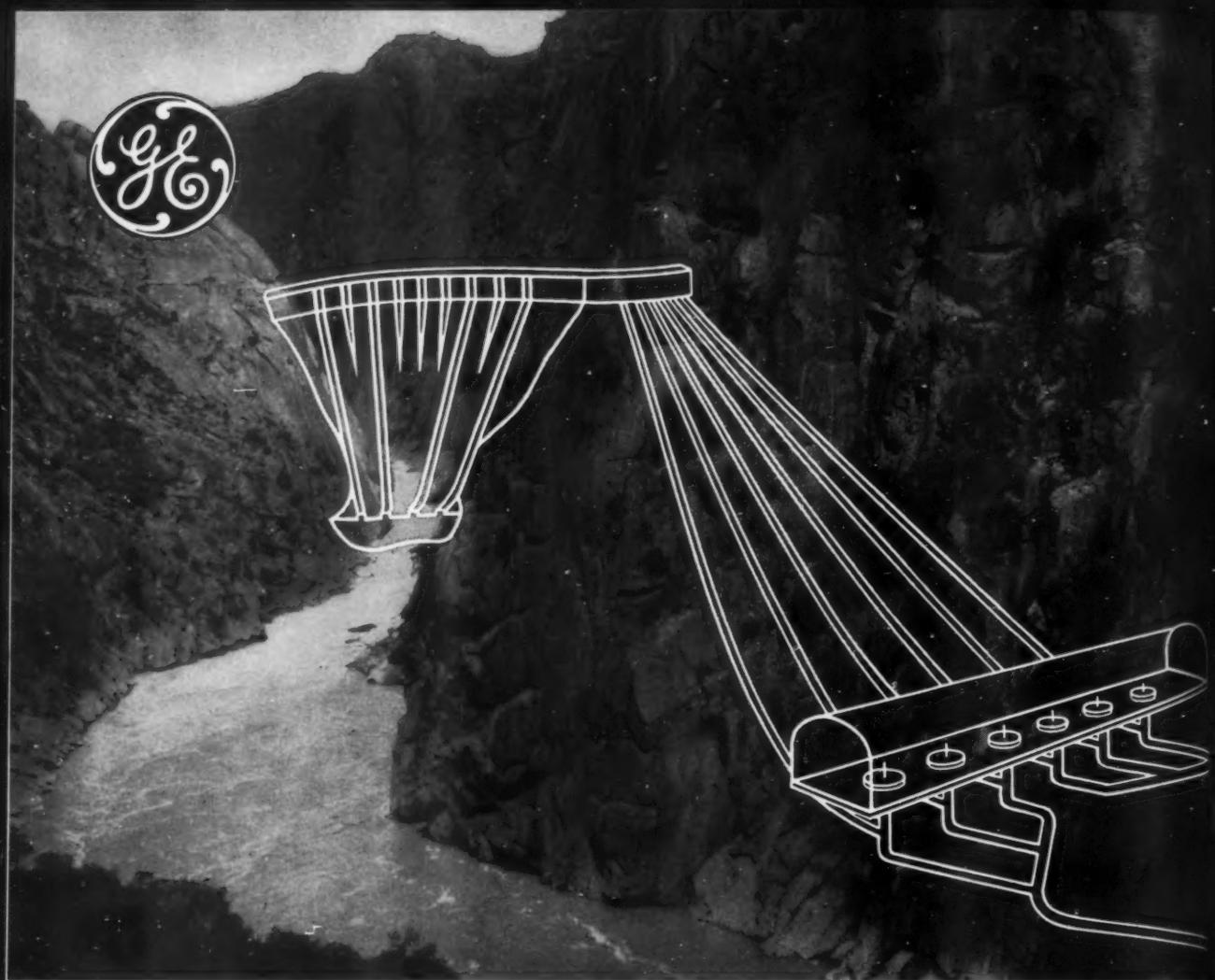
Norsk Hydro
Synchronous Condenser
36 MVA – 10,0 kV – 750 rev/min



Moron
Synchronous Condenser
30 MVA – 13,2 kV – 1000 rev/min

ALLGEMEINE ELEKTRICITÄTS-GESELLSCHAFT

Berlin (West) EXPORT DEPARTMENT Frankfurt (Main)



Original site of Aldeadavila with overlay of hydro system

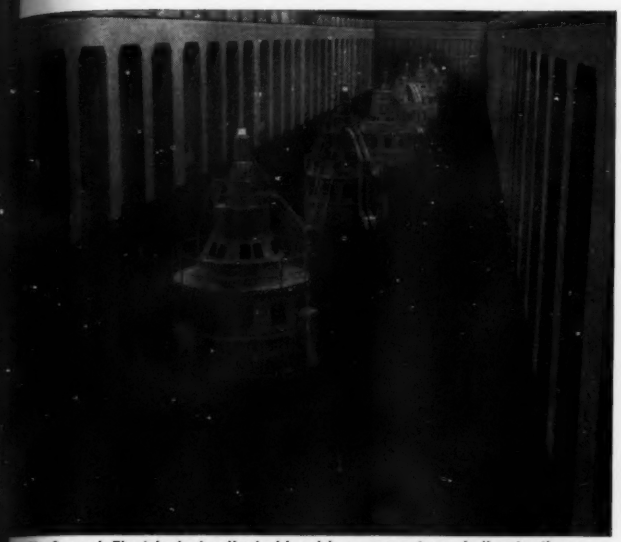
Iberduero S. A. Turns To General Electric To Equip Aldeadavila...Europe's Largest Underground Power Plant

Aldeadavila, scheduled for full operation in 1962, will have a total installed capacity of 756,000 KVA.

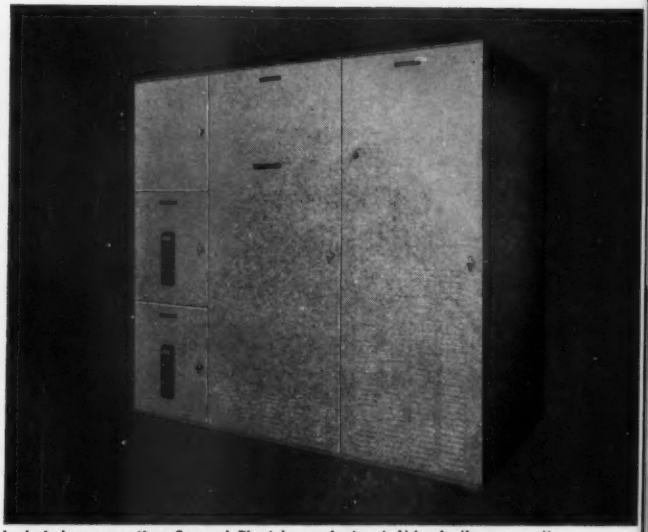
The Aldeadavila Hydroelectric project was born out of one of history's fine examples of international co-operation. In 1927, Portugal and Spain signed an agreement to participate in full utilization of hydroelectric potential of the Duero River. In 1935, Spain's largest utility started their country's program with Esla, the first hydroelectric station in operation on the Duero. Upon completion of Aldeadavila, the full utilization of the Spanish section of the river will be realized.

General Electric is playing a major role in supplying the necessary equipment for this great station. Six G-E 126,000 KVA hydraulic-turbine driven generators will help produce 2-million kilowatt hours per year. This will increase Iberduero's total capacity by some 65%. In addition to other General Electric products, the station will be equipped with G.E.'s new automated load dispatching equipment which will increase dependability and cut operating costs.

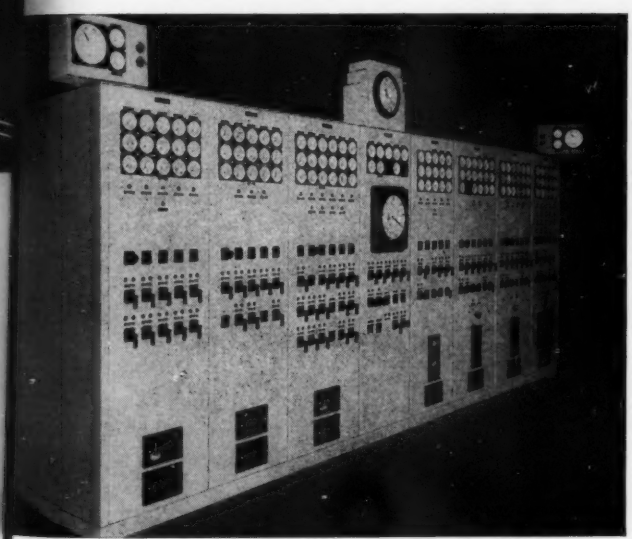
Six Dependable G-E Generators and Other Auxiliary Equipment Will Combine To Produce 2 Million Kilowatts Per Year



Six General Electric hydraulic turbine-driven generators similar to these will be installed and operating at Aldeadavila by 1962. These units will be rated at 126,000 KVA, 0.95 p.f.; 187.5 r.p.m., 13,800 volt 3-phase 50 cycle, and will be equipped with G-E thrust bearings.



Included among other General Electric products at Aldeadavila are excitation and regulator equipment. This indoor field excitation unit, shown here with the doors closed, houses field switch, voltage regulator and rheostat. G-E also manufactures reliable outdoor field excitation equipment.



G-E Duplex Control Switchboards control power generation and distribution. Known as the "Tunnel Type Duplex", it features a walk-through design with doors at both ends to permit access to the interior for easier maintenance and test operations.

Iberduero, S.A. has ordered six generator control desks similar to this for Aldeadavila. This model includes control switches, indicating lamps, indieating instruments and mimic bus. G.E.'s full line of control desks is particularly applicable to continuous process control functions.

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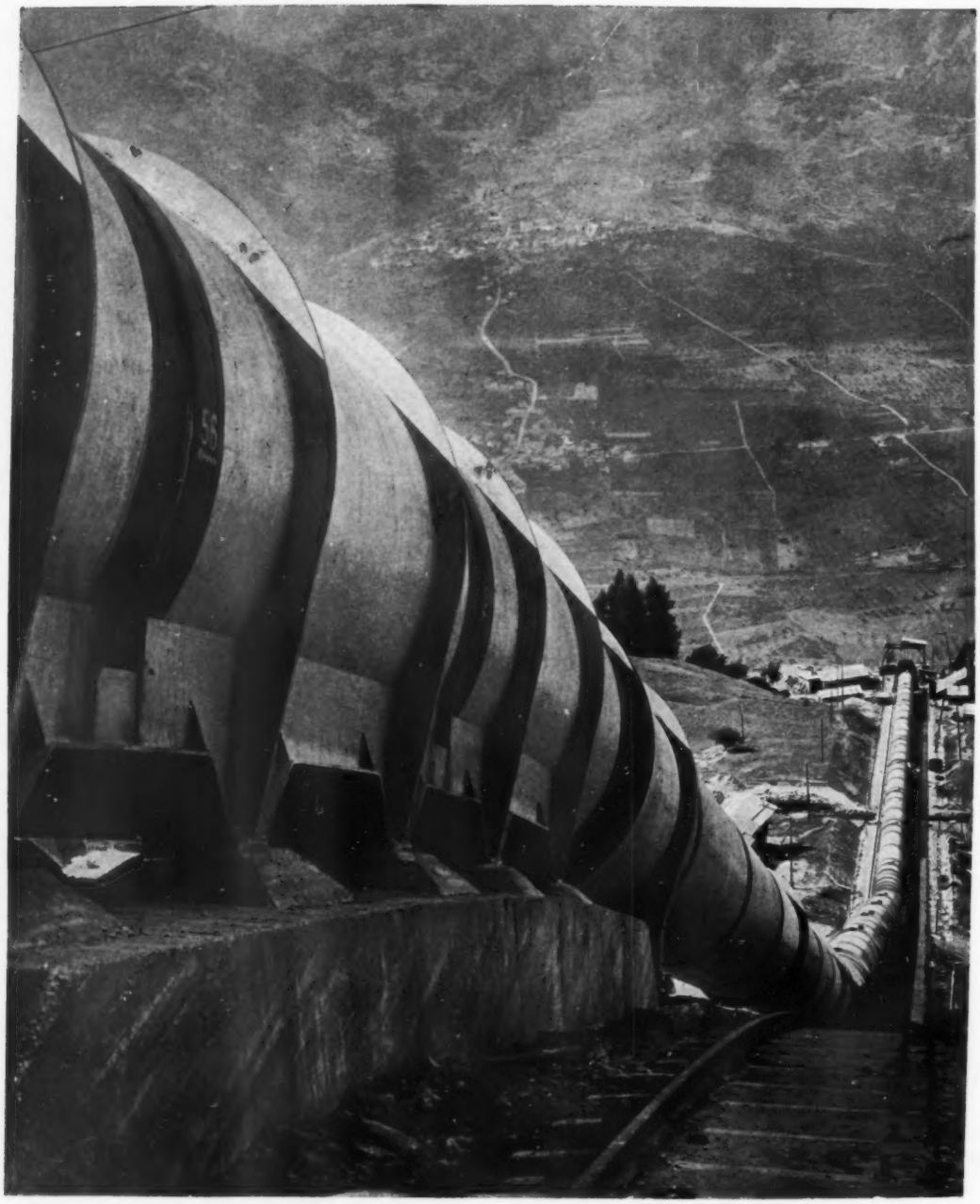

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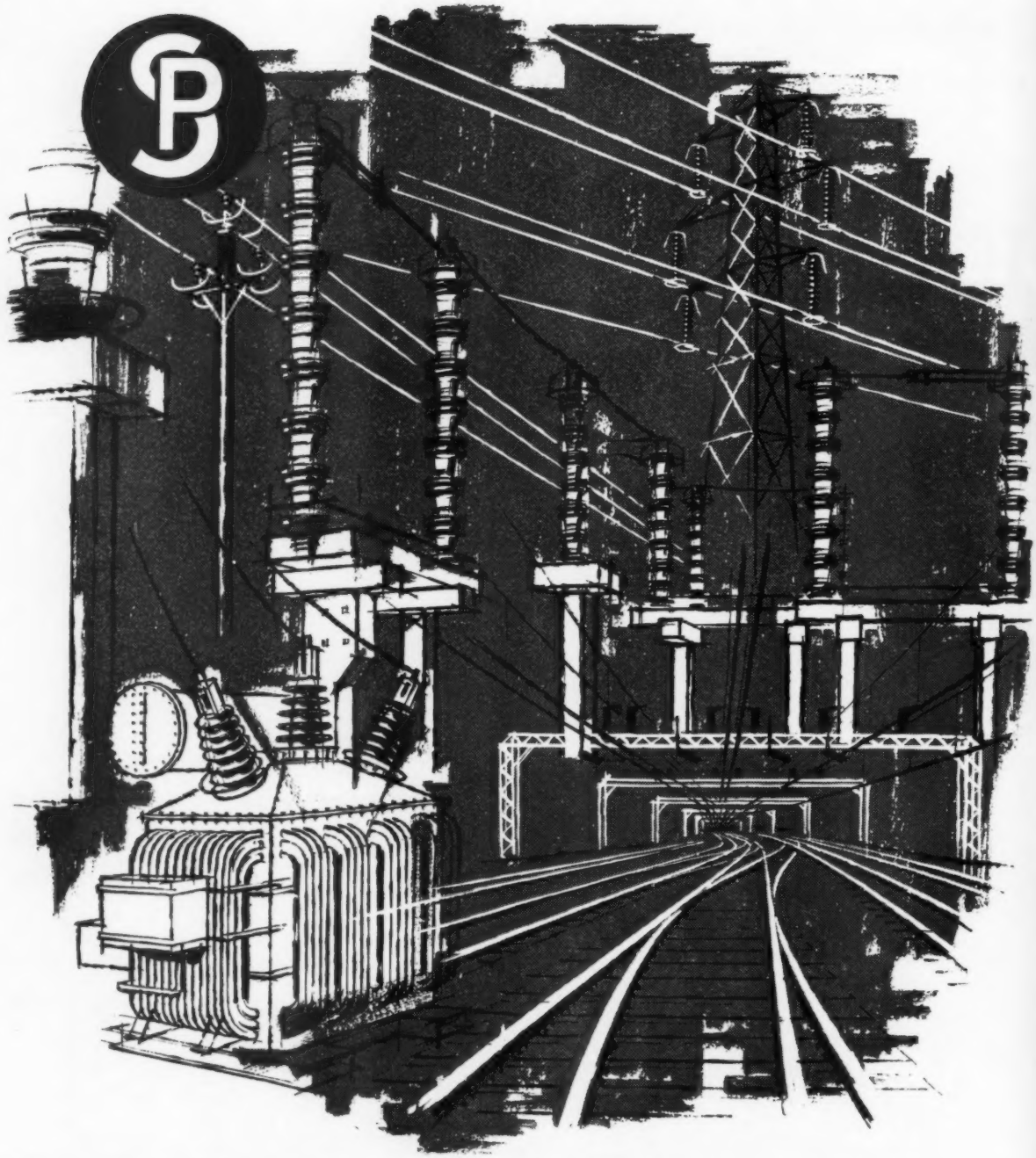

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Interior of Shin power station of the North of Scotland Hydro-Electric Board showing two 12 MW 11 kV 375 r.p.m. generators.

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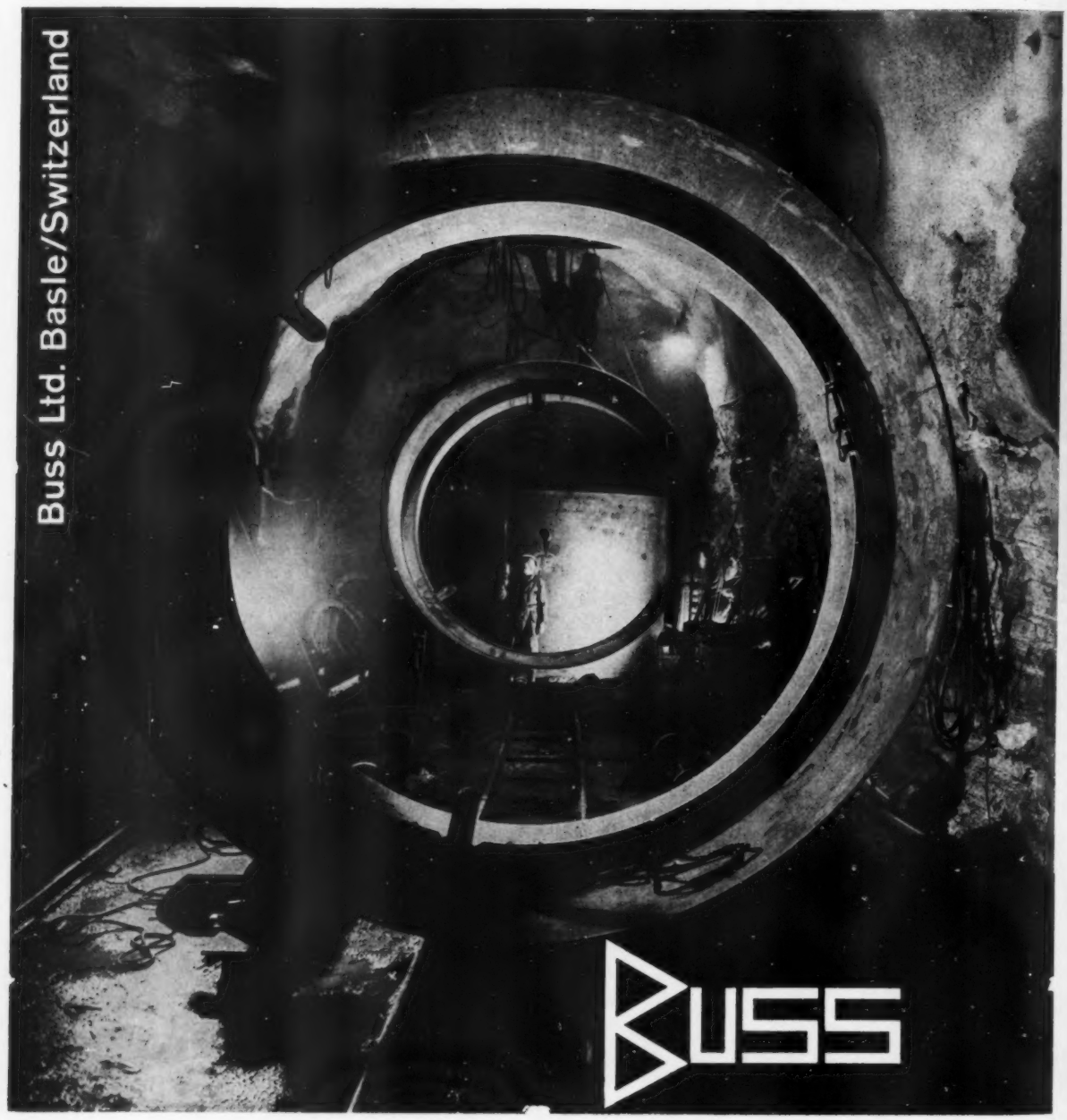

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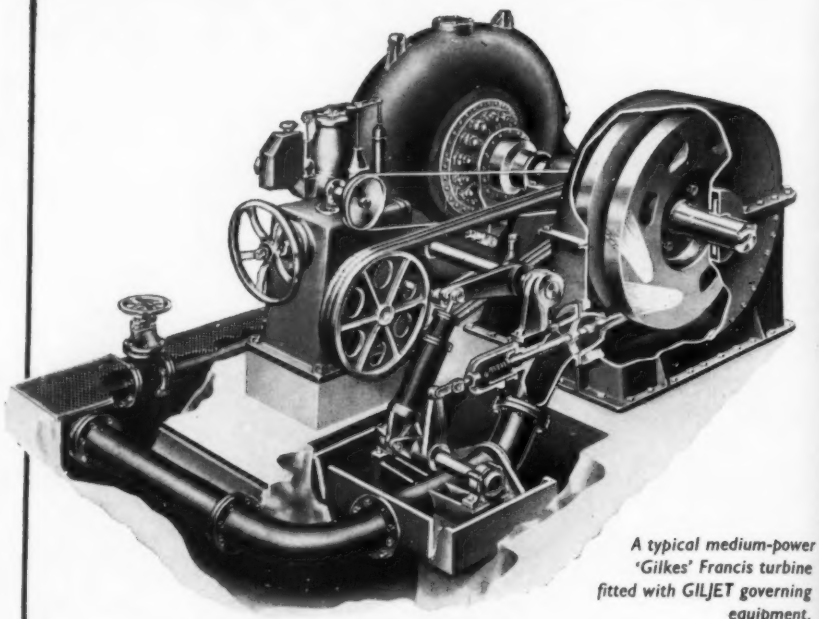
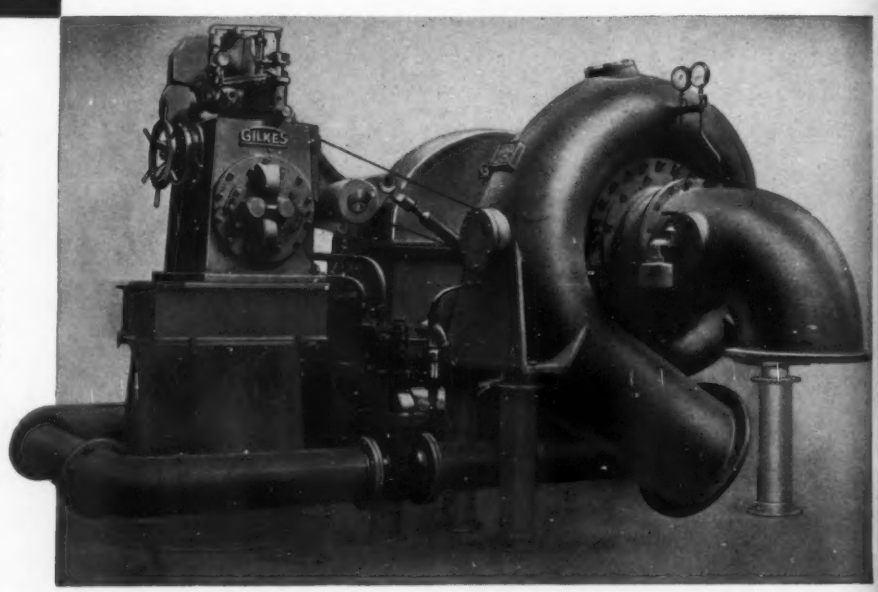


A typical medium-power 'Gilkes' Francis turbine fitted with GILJET governing equipment.

THE GILJET GOVERNING SYSTEM

A 3,100 horsepower 'Gilkes' Francis turbine operating on 340 feet head and fitted with GILJET governing. This unit is installed in the North of Scotland Hydro-Electric Board's Kilmelfort Power Station. The pipeline is 4,700 feet long and there is no surge chamber.



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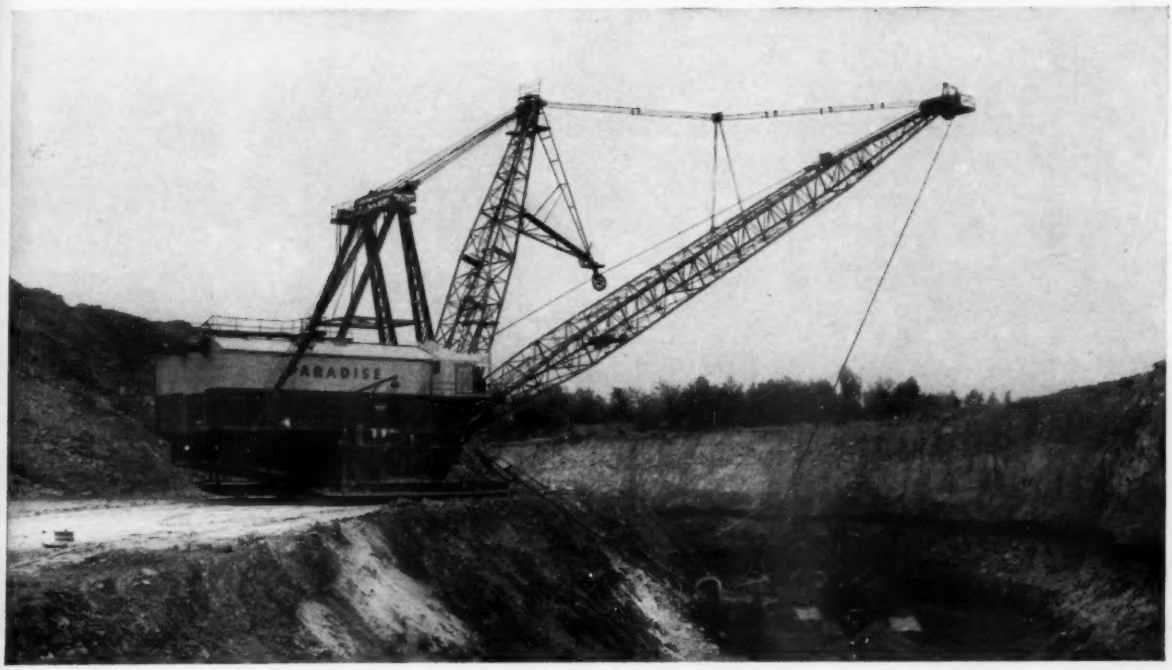

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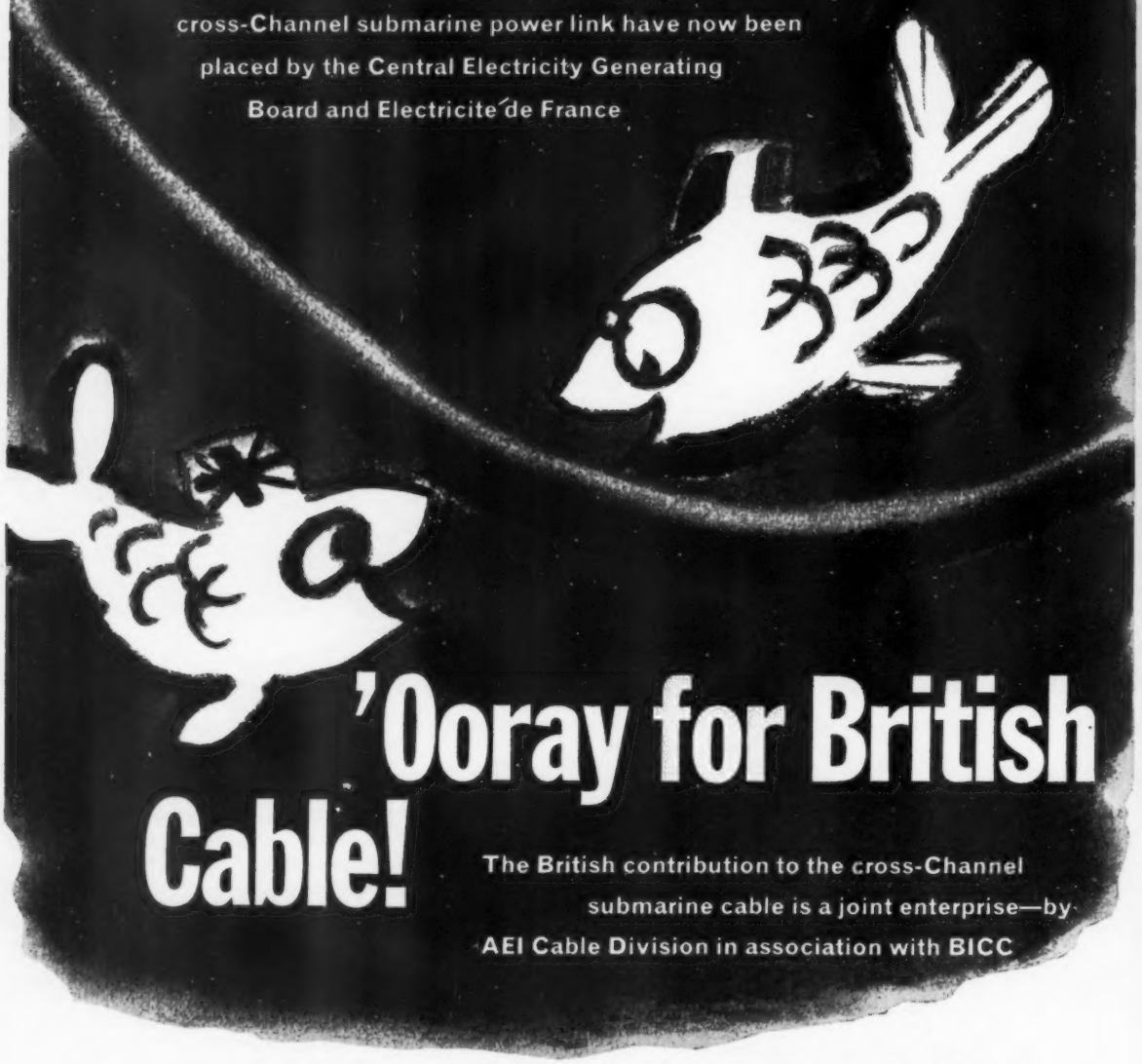
Contracts for the manufacture and laying of the cross-Channel submarine power link have now been placed by the Central Electricity Generating Board and Electricité de France



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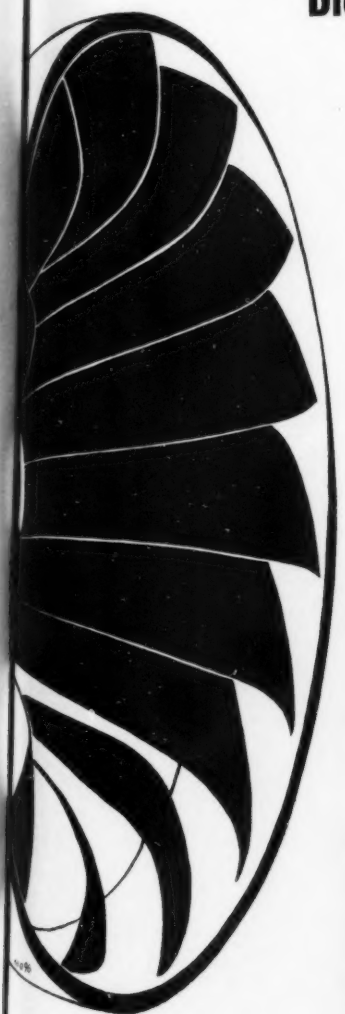

Did you attend the World Power Conference in Madrid?
Did you pay a visit to the Spanish SAUCELLE HYDRO-ELECTRIC POWER STATION on River Duero?

If not, please write for a free copy of our pamphlet No. 1546e which fully describes the four vertical-shaft 86,500 b.h.p., 150 rpm, VOITH FRANCIS SPIRAL TURBINES operating under a net head of 62 m (203 ft) in this interesting power station owned by Iberduero S.A.

The photo underneath shows the guide apparatus and guide vanes of one of the four SAUCELLE turbines in the course of manufacture.

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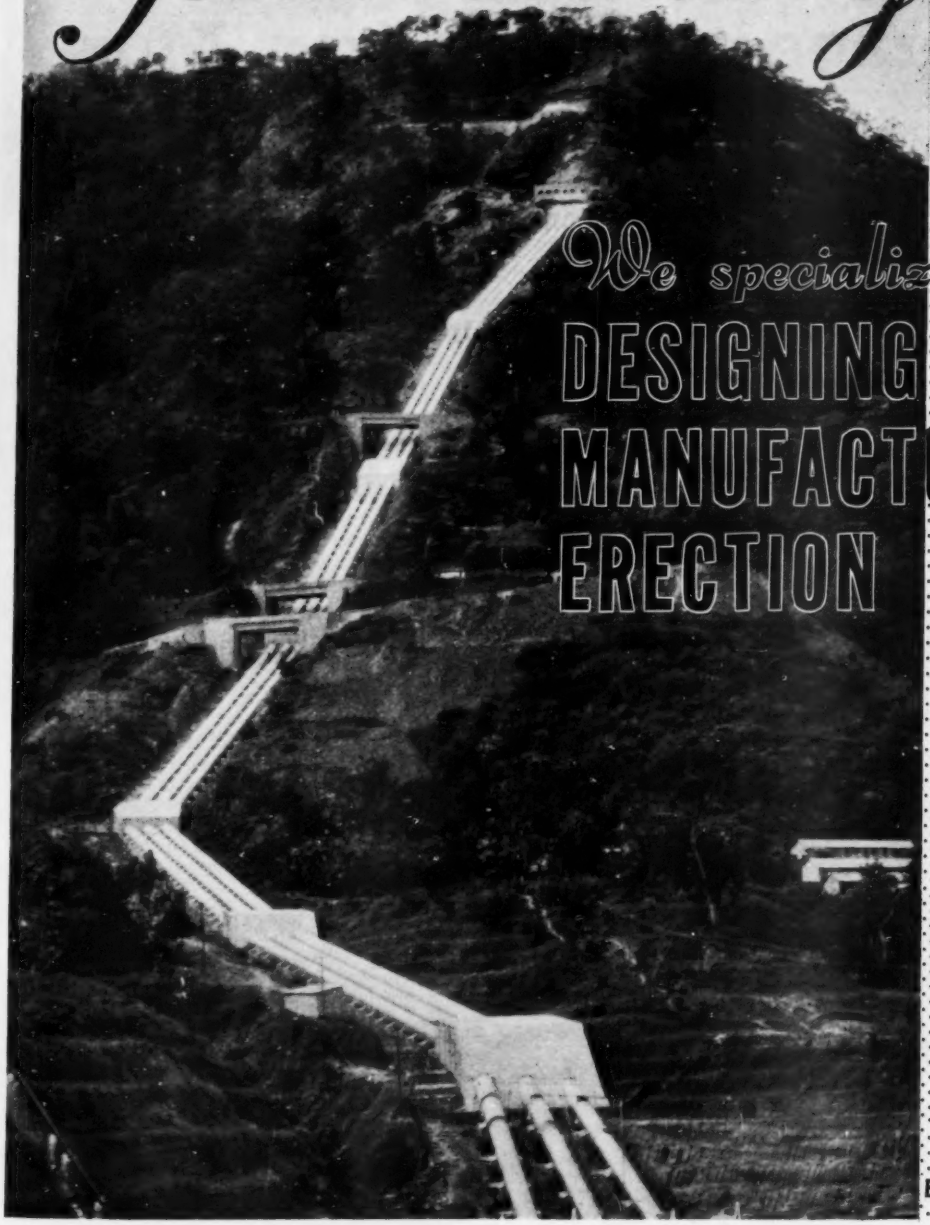

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CONTENTS FOR SEPTEMBER, 1960

Editorial: Choice of Transmission Voltage - - 331

Editorial Notes - - - - - - - 332

Correspondence: World Records - - - 334
René P. Chauvet

Omorigawa Pumped-Storage Plant - - - 335
By Tsutomu Shiwa

Trashracks and Raking Equipment—I - - - 342
By Thaddeus Zowski

Some EHV Transmission Problems - - - 349

The Yanhee Multipurpose Project - - - 352
By Bernard L. Robinson

CIGRE, 1960 - - - - - - - 359

Short Articles: Boreholes Drilled with a Neyrfor Turbodrill—Calgary Power Company—New Boving Butterfly Valves—Actuators for Valve Control—Firth Cleveland Flowmetering Equipment—Caps for Concrete Vibrators - - - - - - 364

Book Reviews - - - - - - - 366

Abstracts from the World Technical Press - - 368

Editor: H. STOREY, M.C., B.Sc., M.I.M.E.

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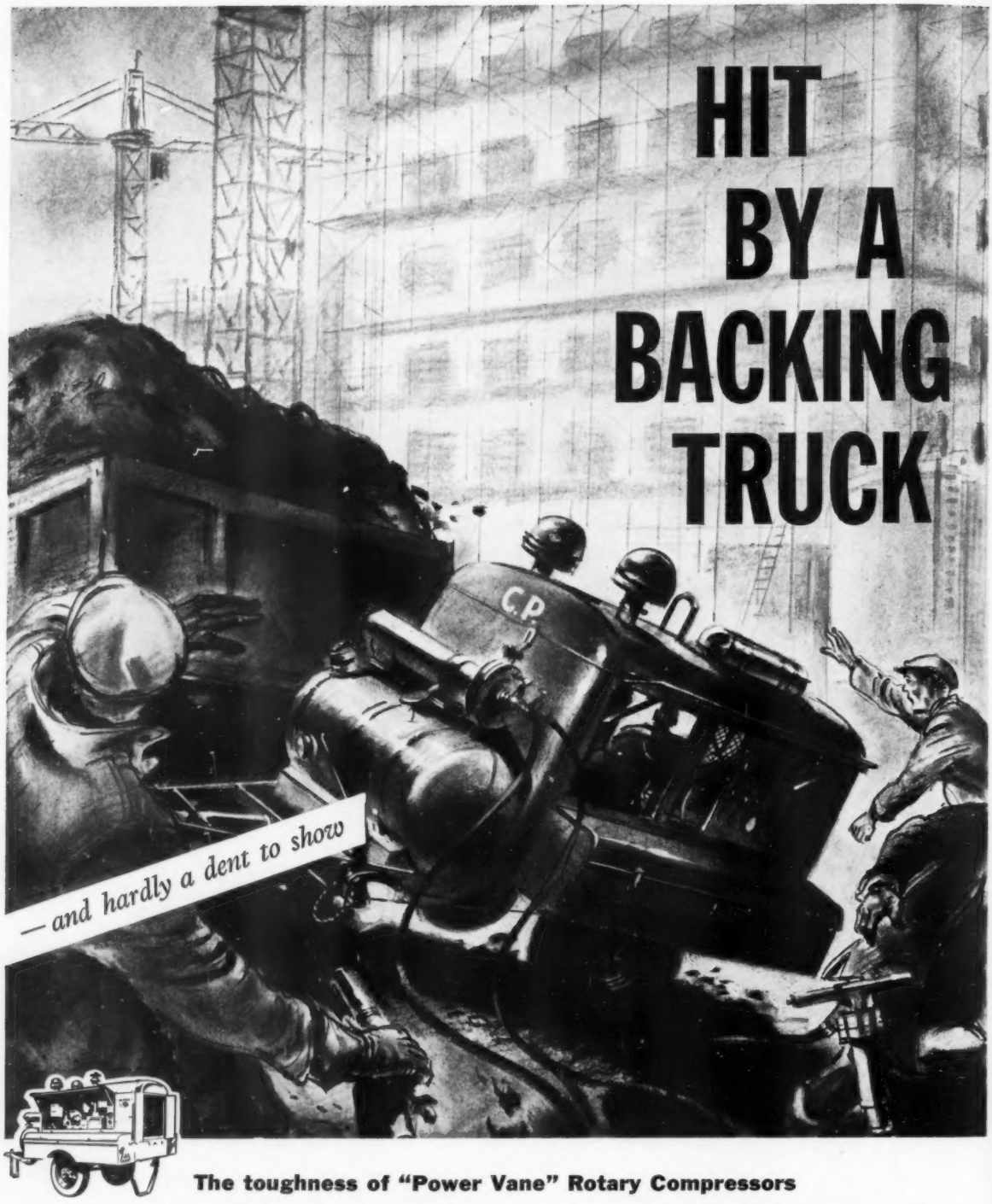

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Choice of Transmission Voltage

IMMEDIATELY the recording of sound on magnetic tape was seen to have become practicable, international standards, accepted all over the globe, were found without any difficulty at all for the size of the tape and the speeds at which it should run, just as gramophone-recording companies, with very little discussion, evolved their own speed standards, again universally acceptable. Electric-lamp sockets are standardised in three or four sizes throughout the world. There are only two major frequencies in use, 50 and 60 c.p.s. Many other instances of universal acceptance of two or three standards, mainly alternatives one to the other, can be given, and the acceptance of these overrides political and technical barriers, and has seldom required much arbitration or even discussion.

It is therefore interesting to speculate why it is that in power transmission there are now several dozens of voltages above 110 kV in use, and with the steady increase in transmission voltage becoming the most important feature in the whole world of power transmission, there is no sign of agreement on an international basis of new voltage levels to which all countries would adhere.

The seriousness of this problem was clearly set out in papers presented to the CIGRE conference held earlier this year and mentioned elsewhere in this issue. One author, the distinguished French engineer, M. Ailleret, of Electricité de France, entitled his contribution "For a Full Consciousness of the Worldwide Disorder Risk of Extra High Voltages." In it he said that "the constant development of power in all electrical systems, the harnessing of very condensed new electrical sources and the difficulties of running lines across crowded areas are bound to lead to an ever-increasing use of high transmission voltages. The range of action of such voltages is now in the thousand-kilometre scale. Such transmission projects go beyond the individual dimensions of systems and even States, and economical disturbances could easily occur if extremely-high-voltage systems could not be interconnected owing to the voltage selection problem on a world scale not having been considered in time."

M. Ailleret goes on to say that "We are living at a critical time when decisions about to be taken on the standardisation of these voltages are comparable to those already taken on the nearly worldwide standard railway gauge or—in the electrical field—to those taken successfully on the standardisation of the worldwide 225 kV voltage range, or unsuccessfully on the complete standardisation of frequencies, as the duality of 50 and 60 c.p.s. can be considered as a failure of the world's electrical industry."

If we consider what happened when it was first necessary to rise above the 220 kV level, we see that urgent needs for higher-voltage transmission in the U.S.A. led to 315 to 350 kV lines being designed and built, without reference to international standards. In Russia, it was found that the original 400 kV line had been somewhat overdesigned, and could safely be raised to 500 kV. In Sweden, the establishment of the 380/400 kV level was followed by the adoption of this level first in Russia, and then in Germany and France, and now 380/400 kV lines are being planned for other countries. But for two most important projects, the Snowy Mountains Scheme in Australia and the Kariba project in Rhodesia, the 330 kV level was estimated as being the most suited.

The International Electrotechnical Commission works hard to provide standard ranges, and (again to quote M. Ailleret) "voltage standardisation may be considered from the sole angle of the equipment manufacturer, to avoid useless ranges while leaving public utilities free to make the wisest choices."

In the CIGRE discussion it was proposed that the best step between two voltage ranges should be one in which the newer voltage was $\sqrt{3}$ times that which it superseded. Thus, the present 400 kV level would rise to 700 kV. It was generally agreed that steps that were too small were thoroughly unjustifiable in the long run; yet such steps continue to be made.

The Chairman of this session, Mr. Philip Sporn, of the U.S.A., himself a notable exponent of the advantage of extra-high-voltage power transmission, added to the pleas made by M. Ailleret and others at the

CIGRE session, for urgent consideration of this matter. It seemed likely that in the years to come the following world voltages would be adopted: 380/400 kV rated, 420 kV maximum; and 660/690 rated, 735 kV maximum. This proposal seemed to meet with wide approval, but CIGRE, it must be remembered, is not a policy-making body and does not even have the semi-official status of the International Electrotechnical Commission. This powerful body is still engaged in discussions on voltage ranges, and its Technical Committee No. 30 has been deliberating proposals for international voltage standards, without yet having reached firm propositions to lay before its member standards organisations.

In this connection an important point of terminology was raised. The term "rated voltage" does not seem to have a sufficiently precise meaning. It is the maximum voltage used as a basis for the design of the insulation of the line and its equipment that is the real determining figure, and by now the ratios that obtain between the maximum voltage and the normal operating levels are sufficiently well known for a rating such as 380/400 rated, 420 maximum to be acceptable as providing a much clearer and more accurate definition of a voltage range than any one figure such as 380 kV. It is hoped that both CIGRE and the International Electrotechnical Commission will clarify this point at least in the near future, and will instruct all its member organisations to use the same terminology.

Among the many advantages of a firm and definite voltage standardisation agreed all over the world would be a substantial saving in research and development costs both on the part of manufacturers and of users. CIGRE itself, with its enormous bi-annual collection of data-filled papers, shows how great this research is at present, and it seems obviously prudent to take any steps that may be possible in the future to rationalise the direction in which research has to be pursued. For example, the design of a 600 kV breaker, if such a voltage level were contemplated, would involve thousands of man-hours of highly technical staff, and much of the effort would not be directly applicable to a breaker intended, a short while afterwards, for the 660/690 rated, 735 maximum system that might then be needed. Additional voltage ranges would bring strong pressure from manufacturers for additions to the systems concerned to be made at those levels, so that they could recoup some of the development charges applicable to the evolution of equipment for that level, by receiving further orders. Thus a multiplicity of standards tends to become self-asserting, and only action by the International Electrotechnical Commission and by the Government-sponsored standards institutions can serve to break this potential deadlock.

In many countries, the capital required for the vast electrification schemes continually being projected has now assumed such a large proportion of the budget of the particular nation concerned that outside help must be called on to provide the necessary finance. It is hoped that the various international financing agencies, who play an increasing part in the development of electrification, will themselves realise that they have some duty laid on their shoulders to insist on standard transmission voltages. There is an old saying in Britain that he who pays the piper calls the tune; and he who pays for the project could just as legitimately call the voltage.

Rio Tuma Project, Nicaragua

THE World Bank has approved a loan equivalent to $12·5 million for the expansion of electric power supplies in Nicaragua. The loan will help to finance the construction of the Rio Tuma hydro-electric power project which includes a 50 MW power plant and a 75-mile transmission line to bring power to the capital, Managua, and smaller towns en route. The new power project will more than double the capacity of the power network serving Managua and the main towns of Nicaragua.

The loan has been made to the Empresa Nacional de Luz y Fuerza, an autonomous entity of the Government. Empresa owns and operates the only transmission system in Nicaragua and serves nearly 70% of the urban population. The company itself distributes power retail in Managua and sells it wholesale to municipal and private power companies for distribution in other towns.

The basis of the hydro-electric scheme now to be undertaken is the diversion of water from the area of heavy rainfall caused by the trade winds in the Eastern part of Nicaragua across the Continental Divide into the drier Western Region and to utilise water flowing down the steeper slopes towards the Pacific for hydro-electric power generation; this will provide energy in the more densely populated Western parts of the country. The project for which the Bank's loan was made consists of the construction of a dam on the upper Rio Tuma creating a reservoir with a gross storage capacity of 410 million cu. m. The water will then be diverted to the Pacific side of the Continental Divide to supply a power station in the valley of the Rio Viejo.

This is the fifth loan made by the Bank for the improvement and expansion of Nicaragua's power system.

Vaiont Dam Completed

BY the time these words appear the last concrete should have been placed on the Vaiont dam. This dam, which was described in our June 1958 issue, is 265·5 m. high and is believed to be the highest arch dam in the world. It will impound 150 million cu. m. of water which will act as a multi-seasonal balancing storage between the Piave and the Cellina systems of the Società Adriatica di Elettricitá. The dam was designed in the SADE Hydraulic Construction Department under the direction of Dr. Carlo Semenza, and has been built by Impresa Dott. Ing. Giuseppe Torno & C., Milan. It has taken about three years to build, including the preparation of the site.

Mangla Dam Project

THE plans of the Mangla dam multipurpose project, in West Pakistan, have been revised so that construction will be carried out in two phases which would take eight years to complete. The total cost of this large project is now estimated at Rs. 2,000 million. Under the revised plan, the length of the dam will be extended from 9,000 to 11,000 ft. and its height will be raised from 420 to 470 ft. The storage capacity of the reservoir will then be increased by 60% and the capacity of its power house will be raised by 15%

For the construction of the first phase of the project, tenders will be invited from all over the world.

The main tender is expected to be awarded in November and construction will then begin from July, 1961. The first phase calls for a dam 420 ft. high and 11,000 ft. long to harness the river Jhelum, and the construction of a power house with two generating units each of 85 MW capacity. The reservior will cover an area of about 125 square miles and will have a storage capacity of 5·3 million acre ft. The sum of Rs. 1,370 million will be spent on this phase of the development.

In the second phase, all the embankments will be raised by 50 ft. so that their elevation will be 1,274 ft. above sea level. The reservoir storage capacity will consequently be extended to 8·5 million acre ft. The second phase of the programme also calls for the installation of two more units in the power house thus increasing the total generating capacity to 340 MW.

The consulting engineers on this project are Messrs. Binnie Deacon and Gourley of the United Kingdom associated with the Harza Engineering Company International of the U.S.A., and Preece, Cardew and Rider of the United Kingdom.

Turbines for Welsh H.E. Station

THE Central Electricity Generating Board's new hydro-electric power station at Cwm Rheidol, Wales, will have two Boving turbines of the vertical Francis type. Each of these turbines will operate at a speed of 600 r.p.m. and will develop 25,000 h.p. under a head of 630 ft. The output will be 18 MW. Site erection began early in April of this year and the station is expected to be commissioned towards the middle of 1961.

Aschach Contracts

THE major contracts for the supply of the equipment of the 264 MW Aschach power station (described in WATER POWER, December 1959, p. 466) have now been awarded by Donaukraftwerke AG. Of the four turbines the orders for two have been placed with Voith, St. Pölten, and Voith, Heidenheim, and for the other two with Andritz and Escher-Wyss. Elin-Union has received the contract for the four 85 MVA generators. The order for the bridge carrying the track of the service gantry crane has been split between Waagner-Biró, Vienna and Graz, who will build the three-span section of the structure across the locks, together with the 90 m. track embedded in concrete on the roof of the power block, and the Vereinigte Österreichische Eisen- und Stahlwerke (VOEST), Linz, who will supply the six-span 156 m. section running over the spillway block. VOEST will also carry out certain work in connection with the four turbines.

Electricity in Brazil

THE annual report of the Brazilian Traction, Light & Power Co. Ltd. for 1959 announces that the flows in the rivers supplying generating plants were slightly less than in previous years and this led to the introduction of some load restrictions in the São Paulo area. Sales of electricity, however, reached 8,423 million kWh, representing an increase of 7·8%. During the year 99,702 new customers were added to the system, making a total of 1,671,069 at the end of the year. Although no new generating capacity was added during the year the completion of the Santa Branca storage reservoir will increase the dry-season capability of the plant on the Rio system by 250 million kWh. A total of 135,275 kVA of substation transformer capacity was added during the year and while it was thus possible to reduce the number of unfulfilled residential applications for electricity, expansion of the distribution system was hampered by a shortage of funds.

Irish Annual Report

THE Annual Report of the Electricity Supply Board of Ireland for the year ended March 31, 1960, states that the development of significant water-power resources has now been virtually completed and that future additional power requirements will have to be supplied exclusively from thermal stations at an inevitably higher cost. Nevertheless, the collection of data with a view to the investigation and possible later development of further water-power resources continued during the year under review, the number of undeveloped rivers under observation being 17.

Ireland now has a total generating capacity of 688·5 MW, of which 219 MW is hydro-electric. During the year the total units generated and purchased amounted to 2,096 million kWh, an increase of 10·4% on the previous year. Of this total, hydro-electric production was 747 million kWh as against 782 million kWh during the previous year. In spite of this decrease, hydro-electric generation was some 6% above the long-term average.

Conference on River Valley Development

THE various problems of river valley development were discussed in a four-day research session of the Central Board of Irrigation and Power, Government of India, held at Trivandrum. Chief engineers and research workers from all over India participated in the meeting as well as engineers from Ceylon, the Technical Co-operation Mission of the U.S.A., the UNESCO and other international organisations who participated in the deliberations. About 50 technical papers covering various subjects such as model and prototype studies of hydraulic structures and their design, problems pertaining to river training and flood protection, design of canals, hydrology, soil technology and foundation engineering, irrigation practices, rural electrification and construction materials, were read and discussed.

Loan for Mexican Scheme

IT is reported by Banco Nacional de Comercio Exterior that the Mexican Government has negotiated a loan from a French consortium—Banque Nationale pour le Commerce et l'Industrie—of nearly $72 million for the construction of the Infiernillo dam on the Balsas River. About half of this credit will be devoted to the purchase of capital equipment from abroad. The station will have a capacity of 500 MW. It will help to develop one of the most backward regions in the country and will lend impetus to the exploitation of the iron-ore deposits at Las Truchas, will improve the power supply to Acapulco and its important tourist trade, and expedite development of the coastal zone of Jalisco.

The Mexican Government has also purchased a group of seven power companies operating in Mexico and hitherto owned by the American and Foreign

Power Company. It is intended to offer opportunities for the foreign capital so freed to be reinvested in Mexico.

Orange River Project

SIR ALEXANDER GIBB & PARTNERS have just prepared a preliminary report on a large hydro-electric project on the Orange River, 80 miles from its mouth on the Atlantic Ocean coast of South Africa. A dam 500–550 ft. high has been suggested, and a preliminary estimate of the volume of concrete required is 2,000,000 cu. yards. The reservoir created by the dam is estimated to be 110 to 120 miles in length, the total capacity of the reservoir being 22 million acre-ft. Based on a cupola arch dam 550 ft. in height, and a power-house capacity of 420 MW the total cost of the project, subject to detailed investigations, is estimated to be £47,000,000. The basic cost would thus be £112 per kW installed.

In their report the consultants have stated that the construction of the dam, in which 400,000 tons of cement would be used, warranted the construction of a permanent cement factory which would supply the whole of Namaqualand and South West Africa with cement once the dam was completed. At the moment, cement for these two regions is obtained from the Union of South Africa.

A labour force of about 1,200 Europeans and 4,400 non-Europeans would be required. It is foreseen that the whole scheme could be completed in six years, that is by 1967, if the general plan of the project is accepted by the South African Government this year.

First Tubular Turbine in Sweden

AFTER several years research and development work, KMW and ASEA have now completed the first tubular turbine unit in Sweden. The turbine was designed and constructed by KMW, whereas the generator section is from ASEA. After separate shop erection and trials of turbine and generator, the two sections were assembled at the site, Skogsforsen power station in Southern Sweden. The unit has now been successfully started up. It will produce 4,875 h.p. at a head of 14 m. and a speed of 250 r.p.m., and is in principle a horizontal Kaplan turbine directly connected to an asynchronous alternator. The alternator is arranged concentrically in the waterway so that the stator casing forms an extension of the internal wetted perimeter of the turbine. This setting provides a straight waterway with essentially axial flow.

Dam Investigations in Pakistan

THE results of a preliminary field investigation on the Tarbela dam project is expected to be submitted to the Water and Power Development Authority in Pakistan by the consultants later this year. According to present estimates the project will cost about Rs. 1,500 million, excluding power-plant cost. The main dam will be built on the river Indus, 30 miles upstream from Attock, and will be 375 ft. high and 10,000 ft. long. The resulting reservoir will have a storage capacity of 6 million acre ft. and the project will generate 1,100 MW when finally completed.

Work is progressing satisfactorily on the Rawal dam located in the vicinity of Islamabad and water will begin to be impounded behind the main dam structure very shortly. The Rawal dam project is on the river Kurang about nine miles from Rawalpindi. It is a masonry dam 80 ft. high and about 820 ft. long. The maximum storage capacity of the Rawal lake will be about 53,000 acre ft. with a surface area of about three square miles. The cost of the dam project has increased from Rs. 6·3 million to Rs. 16 million. The plant will cost nearly Rs. 3 million.

WAPDA experts are now surveying, planning and designing a new dam across the Hub River which will irrigate about 75,000 acres of land in the Karachi area. The project is expected to be completed in about three years.

Cross-Channel Power Link

A £610,000 contract for power cables across the English Channel has been placed by the Central Electricity Generating Board with Associated Electrical Industries Limited and British Insulated Callender's Cables Limited. These two cable-making concerns will lay half of the cross-Channel submarine power-cable link which will connect the national electricity systems of Britain and France. The other half will be laid by cable-making companies appointed by Electricité de France. The connection will transfer up to 160 MW from one system to the other at peak periods and transfer power at other times to meet conditions such as surplus or shortage of water at hydro stations. The contract calls for the manufacture and laying of two similar 15-mile lengths of single-core submarine cable and two related land cables, the work being divided equally between BICC and A.E.I.

Correspondence

World Records

To the Editor, WATER POWER

With reference to Sr. Bhering's letter and your editorial comment in your July issue, the claim that Furnas will be the largest station in the Southern Hemisphere must surely give place to Kariba, the civil-engineering work of which has been provided for a final capacity of 1,500 MW.

RENÉ P. CHAUVET,
E.T.E., Hilla, Iraq.

[Kariba will undoubtedly be the largest station in the Southern Hemisphere when it is completed, but as in the case of the pumped-storage plants discussed in our editorial comment to Sr. Bhering's letter, the validity of the respective claims rests on the sequence of completion dates. The first stage—600 MW in capacity—of the Furnas development is now under construction and should be completed by the end of 1962; the final stage, raising the capacity to 1,200 MW, is due for completion in July 1965. On the other hand, no date has yet been decided for the completion of Kariba, although it is expected to be in the early 1970's. The record of Furnas should therefore hold good for at least five years, even assuming that Kariba is completed as planned. The first stage of Kariba is also 600 MW but the second stage is to be of 900 MW capacity.—THE EDITOR.]

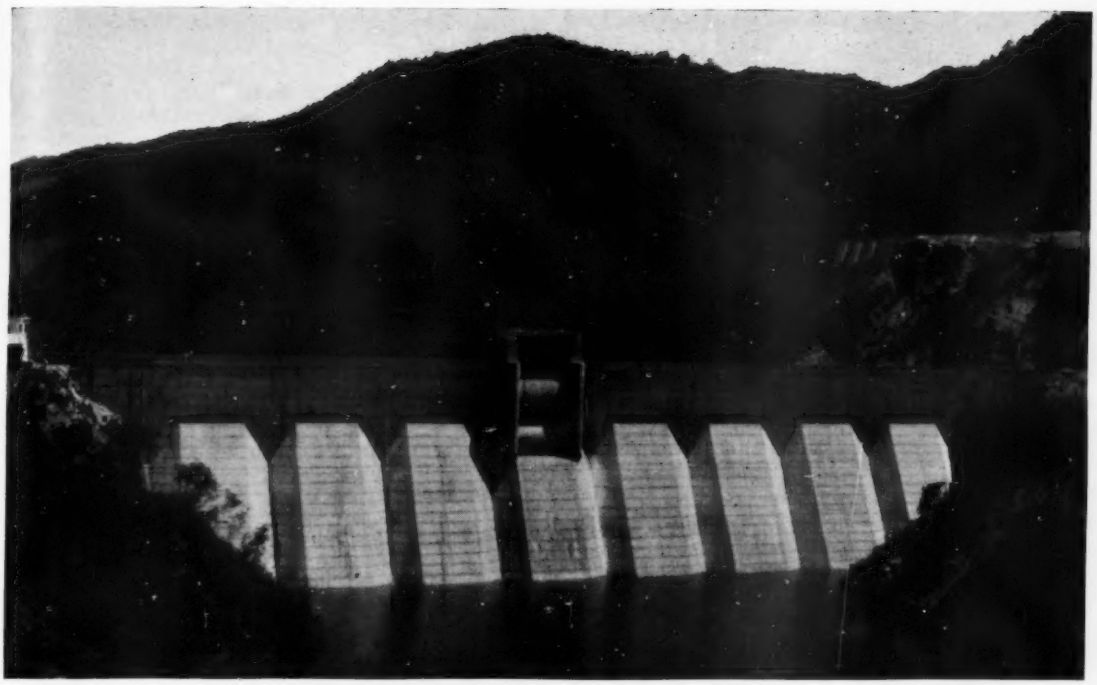

Fig. 1. An upstream view of Omorigawa dam

Omorigawa Pumped-Storage Plant

This station on the Yoshino river contains Japan's first reversible pump-turbine set, and the necessary storage has been impounded by a hollow gravity dam

By TSUTOMU SHIWA*

SHIKOKU island, which has an area of 18,380 sq. km. and a population of four million, is one of the four main islands of Japan. There are two mountain ranges nearly 2,000 m. high and rivers which run generally south, east and west. Most of the rivers are short with steep slopes, except for rivers such as Yoshino and Shimanto, which have a length of nearly 200 km.

The island receives an average of 2,200 mm. of precipitation annually, the amount varying from 1,600 mm. in the north to 2,500 mm. in the south. Generally speaking, the rainfall is moderate from March to October and the island is dry in the winter from November to February. Sometimes the island suffers from disastrous floods due to heavy rainfall and strong winds, especially in August, September, and the first half of October.

The theoretical capacity of the Shikoku power plants is 673 MW, as against a demand for 500 MW. About 65% of the capacity is furnished by hydro-electric plants and 35% from thermal plants. These figures, however, can be somewhat misleading. Only 47% of the hydro-electric generation is from plants having reservoirs, the remaining 53% being from run-of-river schemes. The problem of peak loads and even of full normal loads is therefore a serious one. The island is isolated as to power, there being no power connection with Honshu (the main Japanese island), although it is expected that by 1962 an interconnection will be established through a 200 kV transmission line.

In the meantime steps are under way to improve and make better use of the island's own resources by the installation of pumped-storage stations to provide a reserve of water which would otherwise be wasted during periods of heavy rainfall.

The reversible pump-turbine installed at the Omorigawa hydro-electric power station, to which the article refers, has been in operation since August 1959. The capacity of the machine is 12,200 kW as a generator, and it requires 14,300 kW as a pump. It is located in the uppermost reaches of the Yoshino River, and although the area through which the river flows is only 21·5 sq. km., the average flow is 1·6 cu. m. per sec. and the effective head is 118 m. This water subsequently passes through five power stations on the lower reaches of the river, which have a total effective head of 586 m.

* Director, Shikoku Electric Power Co. Inc., Japan.

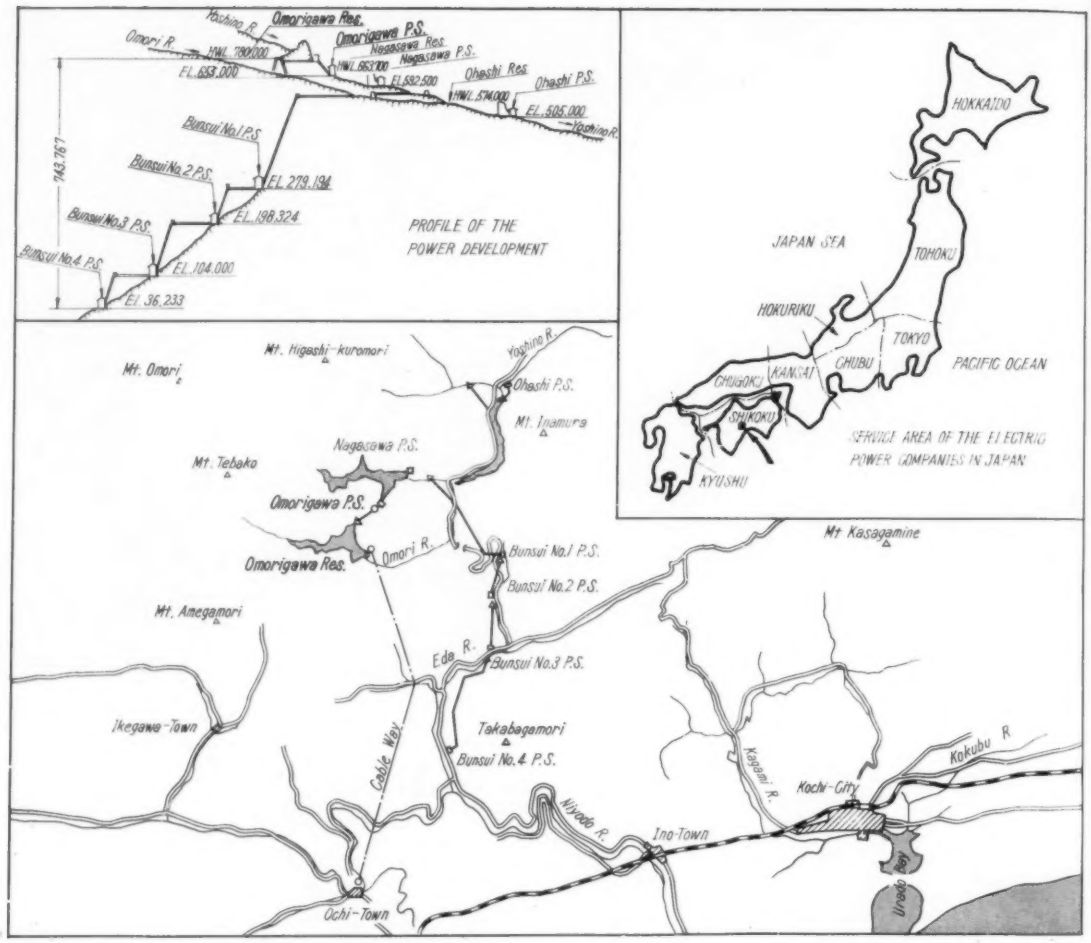

Fig. 2. A layout of the Shikoku system and its geographical position in Japan

When surplus water is available, the pumping operation is utilised to pump water from the Nagasawa reservoir below the power station to the reservoir above the station. Consequently, the Omorigawa power station will have the following functions:

1. Increase the output of all the hydro-power stations on the lower reaches of the river during the dry season.
2. Use the surplus power for pumping water from the Nagasawa reservoir on the lower reaches.
3. Act as a peak-load installation for Omorigawa power station.

The total annual output, including the increased power of the power stations on the lower reaches and the additional power through the pumped-storage system will reach 82,450 MWh.

The Dam and the Conduit

The Omorigawa reservoir, with a maximum drawdown of 35 m. and an effective storage capacity of 17 million cu. m., is formed by the Omorigawa dam. This dam is the second of the hollow gravity type to be designed and constructed in Japan.

In order to determine the horizontal cross sections, the angle of inclination of the face of the dam and the dimensions of the diamond head, photoelastic model tests were carried out. Also three-dimensional photoelastic model tests were made to determine the cross section and angle of inclination of the face of the dam. In connection with buttress sections of the I type, II type and T type, the angles of inclination were altered and studied. Against an earthquake force acting toward the dam axis, which is the largest problem in designing a hollow gravity dam, it was found that tensile stress to a considerable degree occurred near the base in the T type. Alternatively both the I type and II type were available, but the I type was finally decided on. The smaller the inclination on the downstream and upstream faces, the better is the stability. If the inclination is more than 50% the stress distribution becomes non-linear, the principal stress near the upstream face becomes tensile and a strong tensile stress also occurs at the upstream end of the web. On the other hand, if the inclination is sharp, the stress distribution is improved but it becomes disadvantageous from the stability standpoint and the volume increases. In view of these points, it was decided to form both the downstream and upstream faces as an isosceles triangle of 50% inclination.

In a hollow gravity dam, since the outside surfaces of each block are exposed to the air, the natural cooling of the concrete is more effective than in the case of a gravity dam. Consequently, the width of an element was made larger than the width of a block in a normal gravity dam.

Dimensions of the diamond head were mainly determined through two-dimensional photoelastic model tests. In the centre of the diamond head a tensile stress occurs toward the dam axis because of the water pressure, but this tensile stress is cancelled at the upstream end by the compressive stress produced by the water pressure, so that plain concrete can adequately withstand the water pressure.

The thermal stress resulting from the thermal distribution in the diamond head was analysed and checked on the basis of the values measured by thermometers embedded during the construction and calculated by a digital computer. The photoelastic tests for determining the shape of the dam were carried out at the Engineering Research Institute of Kyoto University.

The dam height decided upon was 72 m. above the lowest foundation, the block width 18 m., the crest length 190 m., and thicknesses of the centre section of the dam, 2·5 m. at the top and 71 m. at the base. The maximum design flood is 430 cu. m. per sec., and the spillway water from the centre of the dam is controlled by a tainter gate 8·25 m. high and 9.20 m. wide and is discharged through a ski-jump type spillway. The final design of the ski-jump type spillway was determined by hydraulic tests on a 1:50 scale model. At the end of the bucket there is a two-level sill; the centre portion of the sill is horizontal whereas at the sides it is inclined upwards at an angle of 10°. The water jet is thus diffused and spread evenly over the whole surface of the stilling pool.

Other tests showed that scouring of the river bed would cease when an appropriate depth of water cushion was achieved. The end of the bucket is at a point about 15 m. above the river bed, but hollows were made in the base of the bucket to economise on concrete. The shape of the hollows was determined through photoelastic model tests. The hydraulic tests in regard to the spillway were carried out at the Technical Research Laboratory, Central Research Institute of the Electric Power Industry.

In order to check the actual behaviour of the dam, a considerable number of Carlson-type meters were embedded, there being 43 stress meters, 105 strain meters, 13 seepage-pressure meters, 16 joint meters, three surface strain meters and 65 thermometers. These were embedded in one block at the centre. Also, in order to observe the deflection and movement of the dam, four automatic recording pendulums have been provided.

The dam concrete, totalling 146,000 cu. m., was divided into A and B type mixtures. The cement content of the A-mixture concrete was 230 kg. per cu. m. and this was used for the diamond head and the back footing. Its strength was 277 kg. per sq. cm. at an age of 28 days and 341 kg. per sq. cm. at an age of 91

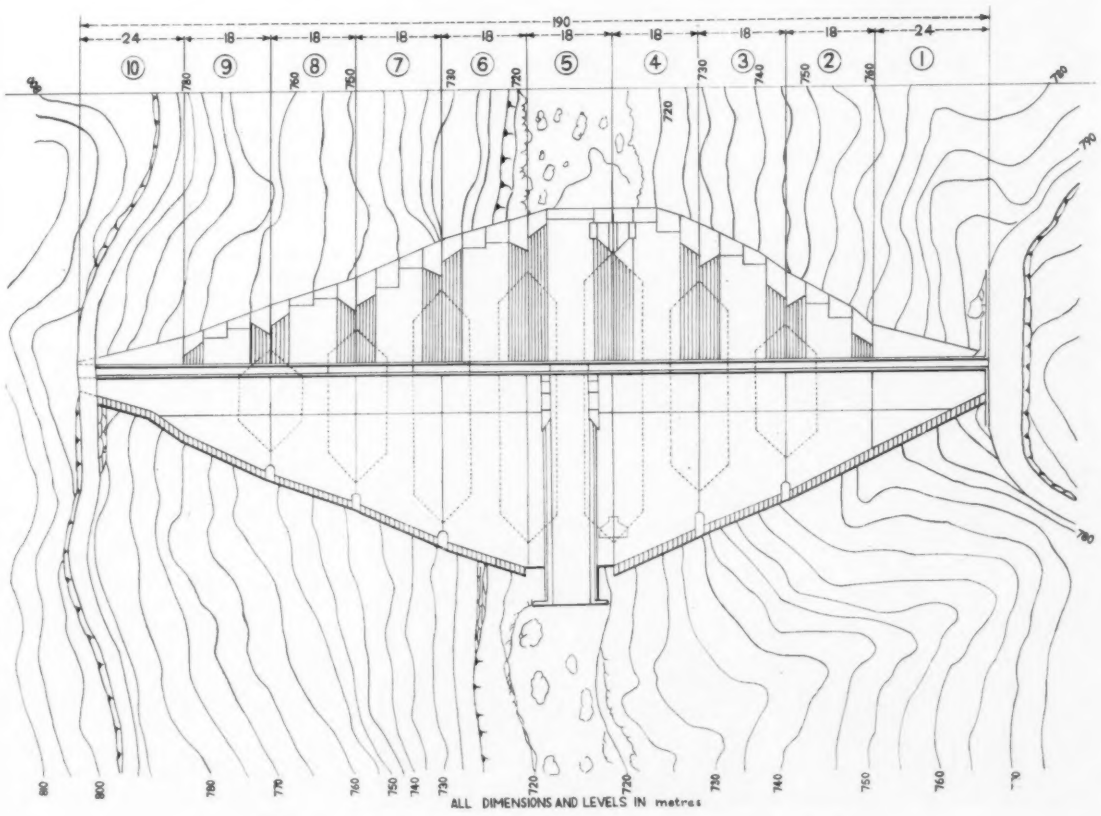

Fig. 3. A plan of the Omorigawa "I" type buttress dam

Fig. 4. A view of Omorigawa power house and substation

Fig. 5. Interior view of the station showing the Hitachi generator

days. The B-mixture concrete had a cement content of 190 kg. per cu. m. and it was used for the web. Its strength was 206 kg. per sq. cm. at an age of 28 days and 279 kg. per sq. cm. at an age of 91 days.

River gravel with a maximum size of 80 mm. was used, and was classified into 80–40 mm., 40–20 mm., 20–5 mm. and less than 5 mm. sizes. As for the cement, slag cement of 50–50 clinker and slag content and low-heat cement with heat of hydration at an age of 28 days of less than 78 calories per gram were used.

The concrete was batched and mixed at a mixing plant having two mixers with a capacity of 0·8 cu. m. each, put in 1·5 cu. m. buckets and transported to the placing position by two 4·5 ton cable cranes. The height of a lift was 1·5 m. and placing was continued every six days.

The greater part of the dam concrete was placed without cooling, but through the summer into the autumn, pipe-cooling was carried out with river water on the diamond head and it was possible through this method to lower the temperature of the concrete by 9·5°C. No concrete was placed during the winter, as the temperature dropped to −15°C.

For joints between the diamond heads, a 3 mm. thick Z-shaped copper waterstop sheet was inserted at a place about 50 cm. from the upstream face and protected by a second sheet 100 cm. behind the first. Between these two sheets, melted asphalt was injected to act as a waterstop.

It was found by boring the river bed and by digging test pits on both sides that the dam site was composed of alternate layers of a thin quartz-chlorite schist and comparatively thick quartz-graphite schist, and that the dip of the strata showed small foldings and was very variable. Joints and fissures were numerous and the fissures included crushed zones. Consequently, the grouting of the dam base was carefully and thoroughly executed.

All consolidation grouting against the fissures and crushed zones of the dam base and the underlying rock was injected to a hole depth of 7 m. and a pressure of 7 kg. per sq. cm. and carried out in two operations. The curtain grouting at the upstream end

of the base, which was in three rows at intervals of 5 m., was injected in two or three stages. The hole depth was 40% of the water pressure and the injection pressure was two or three times that of the water pressure.

The concrete intake tower is located at a point about 1,000 m. upstream from the dam, and is of the front-intake type with an outside diameter of 6 m. and a height of 42 m. It has a screen and a roller gate.

The conduit is a horseshoe-type pressure tunnel with an inside diameter of 2·38 m. and a length of 2,464 m. The surge tank is of the two-chamber type and has an inside diameter of 10 m. and a height of 10 m. The riser has an inside diameter of 4·5 m. and a height of 43·7 m. The lower chamber operates at times of sudden load increases or a pump-trip during pumping.

The lower chamber is divided into upper and lower sections. The upper section has an inside diameter of 3·8 m. and a length of 30 m. and the lower section has an inside diameter of 3·8 m. and a length of 40 m. Both have horseshoe sections. The penstock has an inside diameter of 2·3–1·6 m., a length of 177 m. and thickness of 19–9 mm.

Waterhammer in the penstock when a pump is tripped and the question of the useful capacity of the surge tank were studied by means of model tests as well as by numerical computations and analyses by means of a digital computor. These tests were carried out at the Technical Research Laboratory, Central Research Institute of the Electric Power Industry, while the analyses by the digital computer were carried out by the Shikoku Electric Power Company and Hitachi Limited.

The power station is near the Nagasawa reservoir. It is a semi-underground type reinforced-concrete structure and has an outdoor substation. The tailrace consists of a 24 m. pressure tunnel and a 107 m. open channel. A screen and a roller gate are provided at the outlet, which serves as the intake when pumping.

Electrical Equipment

In using Japan's first reversible pump-turbine and generator-motor, many laboratory tests on scale models were carried out in

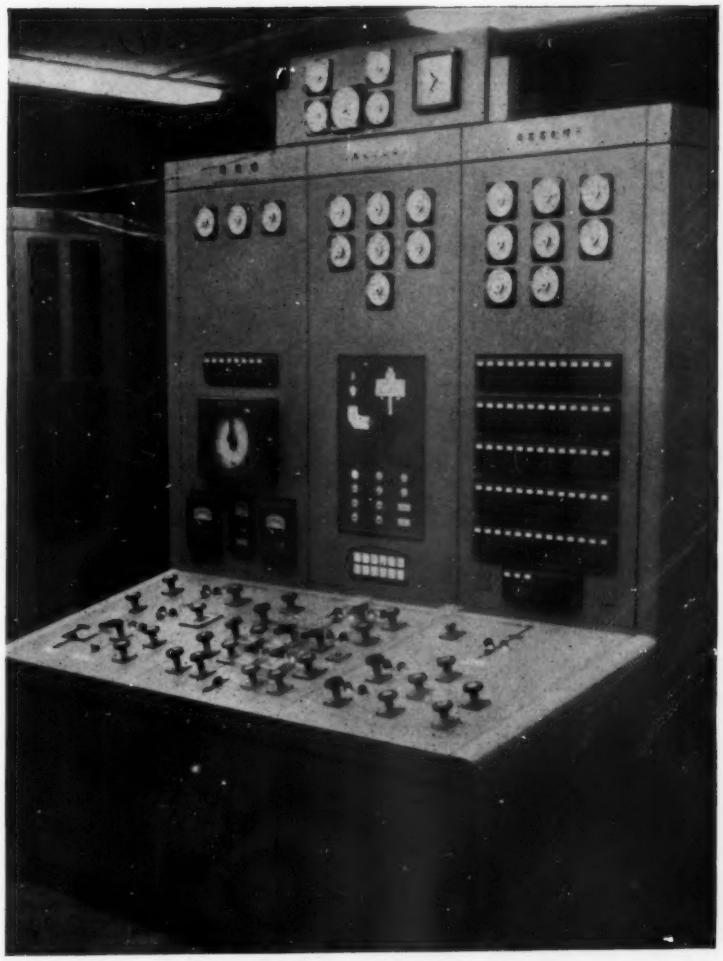

Fig. 6. Main switchboard for the station

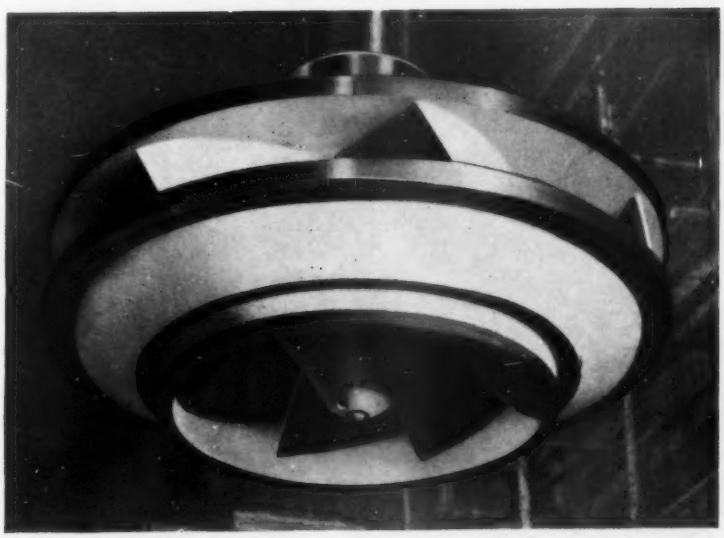

Fig. 7. The Hitachi reversible pump-turbine runner

conjunction with Hitachi Limited. Technical studies were also made together with economic studies of pumped storage. The main subjects of these various tests and researches were:

(a) Performance tests on model runners in order to obtain the same speed for generating and for pumping.

(b) Cavitation tests.

(c) Analyses of transient phenomena during the starting and shutting down of the pump.

(d) System disturbance when the set is started as a motor.

Reversible Pump-Turbine

Omorigawa station is located between the upper and lower reservoirs, and since both reservoirs are deep, the changes in water levels are considerable and the static head ranges from a maximum of 127 m. to a minimum of 81·3 m. Furthermore, the penstock loss is 9·1 m. (at a flow of 12 cu. m. per sec.), so that it was not easy to design an appropriate pump-turbine under these conditions. Research work on runners has had beneficial results and we succeeded in designing and manufacturing a runner in which the ratio of speed that gives the best efficiency as a pump to that as a turbine was 1:1·037, and it was determined, therefore, that the unit could be operated at the same speed as a pump and as a turbine. Extensive research was carried out not only on performance but also on cavitation, the overall characteristics as a pump, bearing tests and other matters.

During installation, the spiral casing and draft-tube liners were firmly secured to the foundations in order to prevent vibration. The vibration in pump operation is very small and is about 0·004–0·005 mm. The speed governor is a magnetic-amplifier-type electro-hydraulic unit. The pump-turbine is a vertical-shaft single-stage single-runner single-discharge Francis turbine, and its ratings as a turbine and as a pump are given below.

TURBINE RATING

Maximum effective head: 118 m.
Maximum discharge: 12 cu. m. per sec.
Maximum output: 12,200 kW.
Speed: 400 r.p.m.

PUMP RATING

Delivery head: 81·3 m.–127 m.
Maximum delivery: 13 cu. m. per sec.
Maximum shaft input: 14,300 kW.
Speed: 400 r.p.m. (reverse).
Suction head: −5 m.

Generator Motor

Reversible operation of an electrical machine is easier than that of a pump-turbine, but careful studies were made for the various parts. The thrust bearing was made suitable for reversible operation and was provided with a means for reducing the friction torque when starting. The damper winding had sufficient heat capacity to accept a restart, and was designed to increase the starting torque and secure stability during operation. Since the frequency of the power-transmission system in Shikoku is accurately maintained at 60 cycles through the automatic fre-

Fig. 8. Omorigawa dam during construction

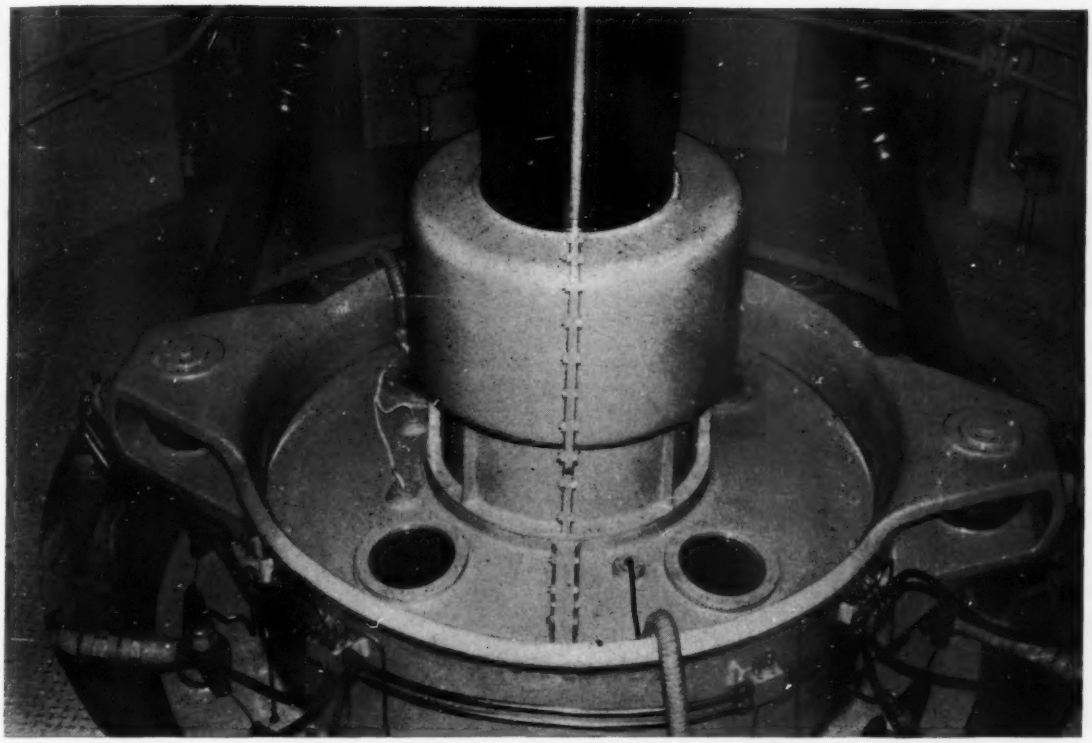

Fig. 9. An assembled view of the reversible pump-turbine installation in the power house

quency-control equipment, it is desirable that the shock given to the system at pump starting be small. To meet this requirement, a reduced voltage of about 5,500 V is given to the motor through the starting transformer to reduce the starting current and load. An a.c. network-analyser was also used to examine the starting characteristics. The machine is rated as follows:

Rated voltage: 11,000 V.
Capacity—
  Generator: 14,000 kVA.
  Motor: 15,000 kW.
Power factor—
  Generator: 0·9.
  Motor: 1·0.
Speed: 400 r.p.m.
Frequency: 60 c.p.s.
Connection: Double star.

Other Auxiliaries

To lower the water surface in the draft tube when starting the pump, two air compressors (15 kW, 23 kg. per sq. cm.) with appropriate air receivers are provided. Since this is a fully automatic power station, automatic strainers and a grease supply system are also provided. Furthermore, to prevent vibration of the guide vanes during pumping, they are locked by compressed-air brakes, but even if these brakes are released the vibration is very small.

Operating Sequence

The Omorigawa power station is connected to the 110 kV system, which is the trunk line of the Shikoku power-transmission system, and is remote controlled from the Bunsui No. 1 power station through a power transmission-line carrier supervisory control system. Since turbine operation does not differ much from that of hydraulic power stations in general, we will confine ourselves to a description of the operating sequence when pumping:—

(a) The water level in the spiral casing and draft tube is lowered by compressed air.

(b) Pressurised oil is fed to the thrust bearing; half voltage is applied to the motor through the starting transformer and the motor is started as an induction motor.

(c) The applied voltage is changed to the full rated value through a slip-detection device, the motor field is excited, and the machine pulls into synchronism.

(d) The air inside the spiral casing and draft tube is released, and when the water pressure in the casing is established, the inlet valve is opened, the guide-vane opening is adjusted to the most appropriate position for the head, and pumping begins.

The time required to change from maximum power generation to maximum pumped-storage operation is about 12 min., while the time required for the reverse process is about 6 min.

Acknowledgment

The author's thanks are due to the Technical Research Laboratory of the Central Institute of the Electric Power Industry, the Engineering Research Institute of Kyoto University, Hitachi, Limited (the manufacturer of the reversible pump-turbine and all the electrical equipment), and the staff engineer of the Construction Department, the Shikoku Electric Power Company Inc.

Trashracks and Raking Equipment

A review of the principles of design and operation of trashracks and raking devices commonly used in hydro-electric power plants

By THADDEUS ZOWSKI*

PART ONE — TRASHRACKS

THE water intakes of hydro-electric plants require effective means of preventing the entrance of floating trash, logs, sheet ice and submerged debris that would interfere with the operation of hydraulic turbines, or that could damage turbine parts such as runners or wicket gates and their operating mechanism, valves, or other hydraulic equipment.

Floating trash is commonly encountered in varying amounts at all surface water intakes, often becoming a serious problem during floods on streams or rivers. The trash carried by the flow may consist of a wide variety of driftwood including anything from logs and large trees to small twigs and pine needles, miscellaneous refuse or debris, grass, various submerged vegetation, and other floating or suspended matter, depending largely on the geographical location. Plants near lumbering areas are usually troubled by debris from upstream logging operations. Other plants may have seasonal problems caused by large quantities of leaves floating on the water in the fall. Difficulties at intakes in cold climates may be created mainly by ice, whereas in warm climates considerable operating problems may be caused by aquatic growths. At many plants heavy runs of trash may occur after weather disturbances such as wind storms or heavy rainfall, or due to temporary conditions such as construction operations upstream of the intake.

Proper protection against trash and floating ice is usually obtained by installing bar-type trashracks (sometimes also called bar screens), or mesh-type screens in the flow passages leading to the hydraulic equipment.

Hydro-electric power stations depend mainly on bar-type trashracks for protection of the hydraulic turbines from undesirable or harmful trash. Mesh screens are used at hydro plants only in special cases where the removal of smaller trash is necessary, or where for one reason or other fish are to be prevented from going through the plant. Mesh screens are more commonly used at pumping stations and steam plants, sometimes in combination with bar-type trashracks which protect the mesh screens from larger debris. At those hydro stations where large debris such as trees, logs, or drift ice is encountered in large quantities, additional protection may be provided by the use of floating log booms and skimmer walls upstream of the trashracks.

This article is concerned mainly with hydro-plant protection against trash, drift ice and other floating matter. Ice problems arising from the formation of frazil ice, or of anchor ice which does not readily yield to raking, are considered to be rather special problems which could not be adequately treated within the scope of this article.

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Importance of Trashracks in Hydro-Electric Stations

The importance of providing adequately designed, constructed, and maintained trashracks cannot be overlooked in striving to minimise unscheduled interruptions in hydro-plant operation and consequent loss of power generation. Furthermore, to permit plant operation at full capacity, the trashracks must be kept clean and free of excessive accumulations of debris which would obstruct flow. It is therefore necessary in most cases to provide suitable equipment for cleaning the racks and for disposal of the trash.

A study of the operating records of several hundred hydro-electric stations in the U.S.A. has indicated that unscheduled shutdowns due to severe trash or ice conditions at the racks averaged about 2% of their total outage time. However, in some individual plants, trash and ice accounted for 10% to 15% of the total outage time. It should be noted that these statistics indicated only the outage time due to complete shutdowns and did not reflect the reduction in plant capacity due to partial obstruction of flow through the racks. Loss of energy due to inadequate cleaning of racks may reach 5% of annual generation or more, especially in low-head plants.

General Constructional Features of Racks

Trashracks used in hydro-electric power stations consist essentially of vertical or slightly inclined steel bars placed parallel to each other and spaced uniformly to permit the use of rakes. The bars are supported in the water passages by horizontal supports which transmit the load developed on the rack bars by the flow, especially when they are partly clogged by trash, into side members or to horizontal back-supporting beams. The vertical bars and horizontal members are usually assembled into panels or sections of convenient size for handling and shipping. The sections are mounted in the trashrack supporting structure of the intake or headworks, usually upstream from headgates, in the enlarged portion of the water passages where flow velocities are lower than permissible in the gate section.

The general construction and details of trashracks vary with the service required, type and size of supporting structure, amount of submergence, and accessibility for cleaning and maintenance. Trashracks may be classified according to their construction and method of installation into three general types.

The first general type consists of sections or panels

of small or moderate width placed adjacent to each other, usually in an inclined plane, and extend from the bottom of the water passage to an elevation above the water surface. The sections may be removed for maintenance and repairs, although they are not installed in guides in the supporting structure. Since small trashrack sections may easily be displaced, it is desirable to bolt them in place above the water surface. Racks of this type have been used for canal headworks, pumping plants, and for most of the earlier low-head turbine installations.

The second general type consists of removable sections which are installed by lowering them in guides placed in the supporting structure, so that the sections may readily be lifted and removed for maintenance. The rack sections may be of the side-bearing or end-bearing type, depending on their principal method of support. The end-bearing type was commonly used in the past, but has been superseded largely by the more economical side-bearing type. Most of the large modern trashrack installations in the U.S.A. with deeply submerged lower sections are of the removable side-bearing type, mounted in a vertical position. Vertical guides embedded in the walls or piers of the intake enable removal of the rack sections and insertion of stoplogs in their place, permitting unwatering of the intake for maintenance of the gates or gate slots. This eliminates the need for providing stoplogs in front of the trashracks, as had often been done in the past. The trashrack sections are placed and removed by use of semi-automatic lifting beams attached to a hoist. The lifting beams may also be used to handle stoplogs or bulkheads.

The third general type consists of sections, bolted in place below the water surface of completely submerged intakes, which may be accessible for cleaning and maintenance only during seasonal drawdowns, or which are cleaned by mechanical rakes or other devices. Racks of this type are usually mounted vertically.

In the earlier designs, prior to the development of large-capacity low-head turbines requiring large trashrack areas, the rack bars were customarily assembled into panels or sections of simple construction and moderate size, about 4 or 5 ft. wide and 10 to 15 ft. high. The parallel rack bars were usually fastened together by tie-rod bolts with pipe spacers. The strength and rigidity of such panels are rather limited, since the rack bars which serve as the primary load-carrying members are weakened by the holes needed for the rod bolts. This leads to the necessity of providing back supports in the form of horizontal beams which span the intake opening and transmit the load from the trashrack bars into the walls of the intake structure. To reduce hydraulic losses caused by the back-support beams, steel I-beams were often encased in concrete or wood of streamlined form. Special shaped beams fabricated from a large pipe on the upstream side with plates forming a sharp tail have also been used.

Trashracks of greatly improved construction were made possible by welding. Racks with the vertical bars welded at their back edge to horizontal members have superseded the earlier bolted or riveted construction. They permit a simplified design with reduced weight and more economical construction. Welded racks are inherently more rigid and less susceptible to deterioration from corrosion than bolted racks.

Fig. 1. Large welded trashrack sections being prepared by sandblasting for painting prior to installing

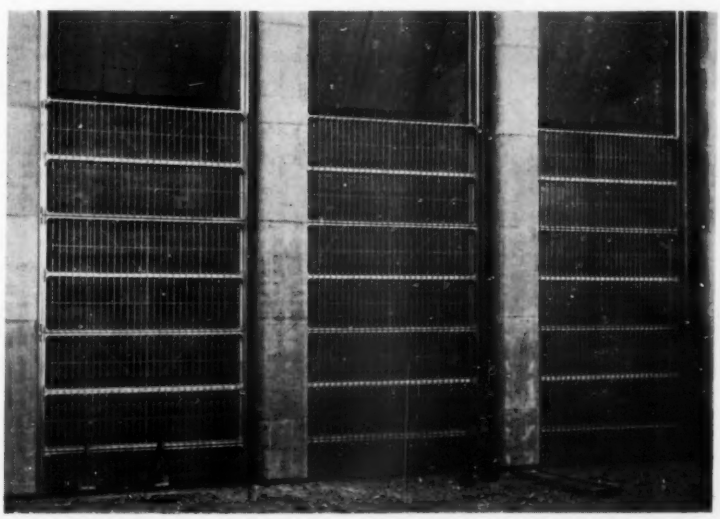


Fig. 2. View of one of the Kaplan turbine intakes at the Priest Rapids development with a portion of the removable trashrack sections installed

With the bars fastened at edge, more space remains for rake teeth to pass. Adequate lateral and back supports are readily built into the welded racks, permitting construction of large removable side-bearing trashrack sections which span the full width of the intake water passages without the aid of backing beams. As an example, Fig. 1 shows several of the welded trashrack sections for the intakes of the Kaplan turbines at the Priest Rapids development on the Columbia River in the U.S.A. Each section is 21 ft. wide by 11 ft. 3 in. high. Six sections are required for each of the three water passages of a turbine. The sections are made self-aligning with each other by the use of built-in aligning cones. Fig. 2 shows a portion of the intake structure during construction with several of the removable trashrack sections in place.

Trashracks are ordinarily made of mild carbon steel of structural quality suitable for welding. Wrought iron, low-alloy steel and stainless steel have been used in some cases, but the gain in strength or durability is seldom sufficient to justify the increased expenditure for these materials.

Setting and Inclination of Racks

Trashracks are set either in an inclined or a vertical position, depending largely on the type of intake in which they are installed and on the method of their cleaning. In so-called low-pressure or low-velocity intakes which are commonly used for low-head plants with moderate daily or weekly headwater variations due to withdrawals from pondage, the racks are usually of the first general type previously described and extend above maximum operating headwater level. Since their upper part is always exposed, they are sometimes called open-type racks in contrast to the submerged type used in high-pressure intakes. The racks should be made accessible from a deck placed safely above floodwater level, to permit their cleaning at times of flood when the need for cleaning is the greatest.

The majority of earlier hydro plants had low-pressure type intakes with trashracks customarily inclined at an angle between 15° and 45° from vertical. The inclination facilitates hand raking because the submerged trash tends to ride up the sloping racks with the flow.

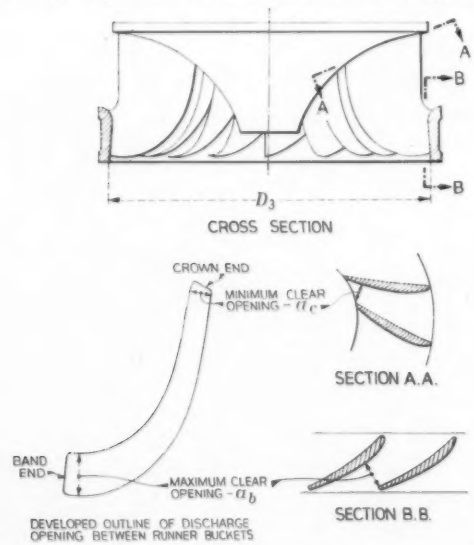


Fig. 3. Location of minimum clear opening in a Francis type runner

Since mechanical rakes have made the inclination of trashracks less important, vertical racks are often being used now for low-pressure intakes in order to economise on the length of the racks and on the intake structure. Although rack inclination tends to reduce head losses, the difference is small for the angles of inclination ordinarily used, therefore it would not normally justify the added length. However, many engineers who have had considerable experience in the operation of plants where trash is a serious problem still prefer the racks to be slightly inclined. It is also interesting to note that vertical setting is used less frequently in European designs than in America.

Where headwater-level variations are large, as in hydro-electric developments with storage reservoirs, deep or high-pressure type intakes are generally used. Such intakes usually comprise the inlets to penstocks or tunnels and are located either in the dam at considerable depth below maximum headwater level, or in separate structures such as intake towers which are commonly used in conjunction with earthfill dams. In deep intakes which are completely submerged most of the time, the amount of trash collected on the racks is small and cleaning of the bars at frequent intervals is not normally required. Occasional cleaning during periods of reservoir drawdown is usually sufficient. If the intakes are at a moderate depth below the minimum reservoir operating level, the top of the racks can be extended to a deck just above minimum water level from which they can be cleaned when the reservoir is drawn down to its lowest level. Since frequent raking is not required and a vertical rack setting is somewhat more economical than an inclined setting, it is advantageous to equip high-pressure intakes with vertical racks of the second general type previously described. Mounting of the racks in vertical guides facilitates their raising above water surface for painting and repairs. In some designs, trash trays have been attached to the rack sections to assist in raising the debris to the surface when the sections are raised for cleaning. Where it is impracticable to draw the reservoir down low enough for trashrack maintenance, or in those rare cases where the intake structure is always completely submerged, it may become necessary to employ divers for cleaning and repair work. However, experience indicates this to be necessary only once in several years. The accumulating of submerged trash on the racks is lessened by its tendency to fall from the racks to the bottom whenever flow through the intake ceases. Permanently submerged intakes usually have racks of the third general type mentioned previously, which should be designed to provide liberal trashrack area.

Trashrack supporting structures for high-pressure and high-velocity intakes are often built out from the face of the intake to form a basket-type structure, for the purpose of gaining rack area required to keep flow velocities low enough to avoid excessive head losses in the racks. A very desirable design of this type consists of a semicylindrical structure designed to guide the water to the intake opening in the normal approach pattern of an orifice.

For vertical-shaft intakes located in the forebay, circular intake towers with cylindrical trashrack structures and vertical racks are commonly used.

Rack-Bar Spacing

The spacing of the vertical or inclined rack bars is one of the most important items to be established in the design of trashracks. It depends primarily on the size and type of turbine to be protected and is also influenced by the size and character of the trash. In some localities an abnormally small spacing may be required by fishery agencies.

The rack bars should normally be spaced so that the clear opening between them is not greater than the smallest fixed opening in the water passages of the turbine. In some instances, consideration is also given to the largest size of timber which can be sheared by the wicket gates.

In Francis turbines, the smallest fixed opening is located in the runner, and is the shortest distance between the buckets or vanes of the runner. It is usually located between the discharge edge of one bucket and the back of the next bucket near the crown of the runner, as indicated by dimension a_c in Fig. 3. The dimension of the minimum clear opening in the runner should be obtained from the turbine manufacturer if possible, but in many cases this information is not available at the time when the trashracks must be designed.

When the detailed dimensions of a Francis runner are not known, a useful approximation of its minimum clear opening can be computed from the discharge diameter of the runner with the aid of the experience data in Fig. 4, which shows the discharge openings in relation to specific speed. The openings are expressed as a percentage of the runner discharge diameter D_3 which is one of the most convenient size parameters for the turbine and related power-house dimensions. The specific speed used here corresponds to the guaranteed full-gate horsepower, which is usually about 95% of the expected or actual full-gate output, under the rated or design head, expressed in the foot-pound-second system of units. The full-line curve shows the minimum clear opening a_c which governs the rack-bar spacing. The dotted line shows the approximate maximum clear opening a_b of the water passages at the runner outlet, near the band. The maximum opening should not be used for selection of bar spacing, but the curve is of some interest as it indicates that in low-specific-speed (high-head) runners the maximum opening between runner buckets is not much larger than the minimum opening, whereas, in high-specific-speed (low-head) runners the clear width of water passages increases considerably along the discharge edges from the crown to the band, thereby providing a better opportunity for trash caught between the buckets in the upper part of the runner to be worked down and cleared of the runner.

The curves of Fig. 4 represent average values of runner openings based on Francis runners of normal design with the number of buckets approximately as shown. If the actual number of buckets is not within the limits indicated in Fig. 4, the openings obtained from these curves should be corrected by the inverse ratio of the actual number to the average of the limits shown.

In propeller-type runners of either the Kaplan adjustable-blade type or the fixed-blade type, the openings between runner blades are relatively large, consequently the openings between wicket gates frequently become the smallest clear openings in the flow passages of the turbine. However, since the wicket-gate openings vary with the load on the turbine, they are not a suitable criterion for selection of trashrack bar spacing. In general, the bar spacing for propeller-type turbines may safely be somewhat larger than for high-specific-speed Francis turbines of the same runner diameter, but it should not be made so large that debris of sufficient size to cause damage to the runner or wicket gates could enter the turbine.

Satisfactory operating experience with propeller-type turbines in a large number of run-of-river hydro stations in America has been obtained with rack bars spaced to provide clear openings from 3 to 6 in. for medium-size turbines (about 100 to 200 in. runner diameter) and from 6 to 10 in. for large-size turbines (about 200 to 300 in. runner diameter). This experience lends support to a useful approximate rule which is used by the author and which establishes the maximum clear spacing between rack bars for propeller or Kaplan turbines as $^1/_{30}$ of the runner diameter. In several installations bar spacings as large as 12 in. have been used successfully with large runners, but such wide spacings are not generally recommended unless there is practically no chance for logs or other potentially harmful debris to enter the turbine. In rare instances, as at the Vargön plant in Sweden, very large Kaplan turbines operate satisfactorily without any trashrack protection.

Impulse turbines have relatively small openings in the flow passages of their nozzles. Close spacing of rack bars is required to prevent relatively small trash such as sticks, twigs, or similar debris from clogging the nozzles. Long sticks can become lodged in the curved portions of nozzle inlet elbows or in the straightening vanes where they cause flow disturbances which may adversely affect the performance of the turbine. They may also interfere with the movement of the needle in the nozzle or prevent its complete closing. An approximate rule, which has been in popular use for many years, is to make the space between rack bars not larger than $\frac{1}{2}$ of the jet diameter at maximum needle opening. For very small impulse turbines, this rule would require a very small and rather impracticable spacing of the bars. In such cases a mesh screen is preferred.

When two or more turbines of different sizes are

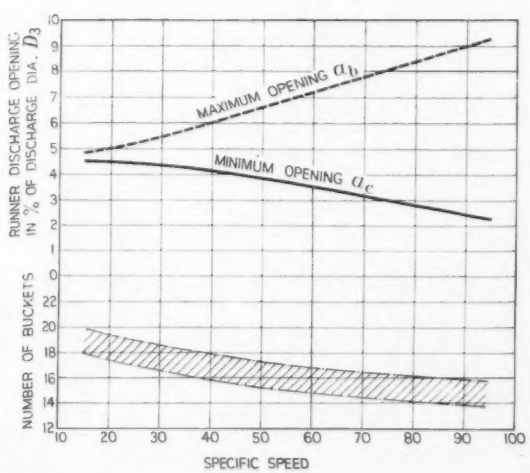

RUNNER DISCHARGE OPENING IN % OF DISCHARGE DIA. D_3
MAXIMUM OPENING a_b
MINIMUM OPENING a_c
NUMBER OF BUCKETS
SPECIFIC SPEED

Fig. 4. Experience data for approximate determination of clear openings in Francis runners

supplied with water through the same trashracks, the bar spacing is normally governed by the smallest turbine. If one turbine is considerably smaller, as in the case of a house turbine supplied through the same intake as one of the main turbines, it is advantageous to provide an internal trashrack at the branch inlet to the small turbine.

Velocities Through Racks

The permissible velocities of flow through trashracks are dependent on several factors, including the type of intake, amount of trash, method of cleaning, rack construction, and sometimes on other special considerations. It is generally advisable to keep velocities as low as economically justified, to minimise head losses and facilitate cleaning. It is also desirable to avoid high velocities through low-head intakes in localities where drift ice is encountered, because fairly large sheets of ice could overturn and pass unbroken between the bars.

The optimum velocities are controlled mainly by economic factors related to the part of total head that can be afforded in loss through the racks and the cost of providing ample trashrack area. The duration of peak loads on a hydro station may also influence the choice of design velocity. The design velocities must be correlated with the structural design of the racks, to assure that the racks will be free from vibration induced by flow, as further discussed herein in connection with structural design.

For convenience, rack design velocities are usually based on the gross area of the racks, or the total cross-sectional flow area either in front of the racks or just behind them, and on the flow corresponding to the rated or design discharge of the turbine under normal rated load and head conditions. However, the maximum velocity through the net rack area must also be given due consideration, particularly in checking the design for possible rack vibration.

In up-to-date low-head hydro plants of large capacity with low-pressure type intakes, rack design velocities based on the gross area are generally about 3 to 4 ft. per sec. These velocities are suitable when trash conditions are not very severe and when racks of conventional design with simple flat bars are used. However, unless the rack bars are sufficiently rigid and stiffened by ample lateral supports, design velocities above 3 ft. per sec. should be used with caution, as some racks of ordinary construction are known to have failed from fatigue cracking of the bars or welds due to vibration with flow velocities in this range. If the racks are to be cleaned by hand raking, the flow velocity should not exceed 2·5 ft. per sec. and preferably should be limited to 2·0 ft. per sec.

The racks of the main river plants of the Tennessee Valley Authority, which are low-head plants with propeller-type turbines permitting wide spacing of the rack bars, are designed for an average velocity of about 3·5 ft. per sec. In one of these plants a velocity of 5 ft. per sec. has been used successfully.

For high-pressure intakes, greater head losses are acceptable as they represent a smaller part of the total head. Consequently, in high-head plants, rack design velocities up to about 10 or 12 ft. per sec. are permissible, if the racks are adequately designed against vibration by providing sufficient structural rigidity and sometimes by the use of streamlined bar shapes.

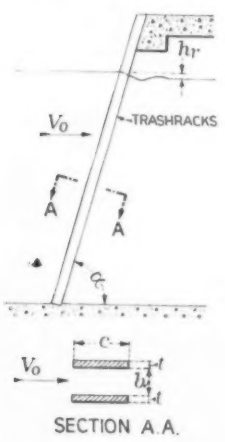


Fig. 5. Head loss in trashracks

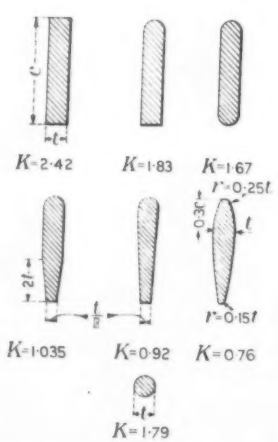


Fig. 6. Values of factor K for various bar shapes

Head Losses in Trashracks

Flow through trashracks is associated with head loss h_r. The loss is mainly due to flow contraction at entry and sudden enlargement of the area at exit from the bar spaces. The frictional loss is negligible. Among the many formulae for calculating head loss, the one developed by O. Kirschmer on the basis of experiments at the Munich Hydraulic Institute (see Fig. 5) is in widespread use:

$$h_r = K\left(\frac{t}{b}\right)^{4/3} \frac{V_o^2}{2g} \times \sin \alpha$$

where: h_r = loss of head through racks, ft.
t = thickness of bars, in.
b = clear spacing between bars, in.
V_o = velocity of approach, ft. per sec.
g = acceleration due to gravity, ft. per sec. squared
α = angle of bar inclination to horizontal, degrees
K = factor depending on bar shape in accordance with Fig. 6.

The values of shape factor K shown in Fig. 6 were established for bars having a ratio of cross-sectional depth c to thickness t of 5·0, excepting round bars. However, variations in this ratio between 2·5 and 10 were found to make very little difference in head losses.

Kirschmer's formula indicates that inclined racks produce less head loss than vertical racks with the same approach velocity, but it is also apparent that the difference is very small for the angles of inclination normally used.

Laboratory tests in connection with the Torr Achilty scheme in Scotland carried out on racks with appropriate horizontal bracing (WATER POWER, August 1955, p. 301) and tests at power plants in Italy have indicated head losses consistently larger than computed by the above formula. Consequently, to obtain safe estimates and to allow for additional losses due to the presence of structural bracing and framing, it is advisable to multiply the value of h_r computed from the Kirschmer formula by a factor of 1·75 to 2·0.

The above computed head losses apply to clean racks. To allow for partial clogging under average trash conditions, it is advisable to assume that about

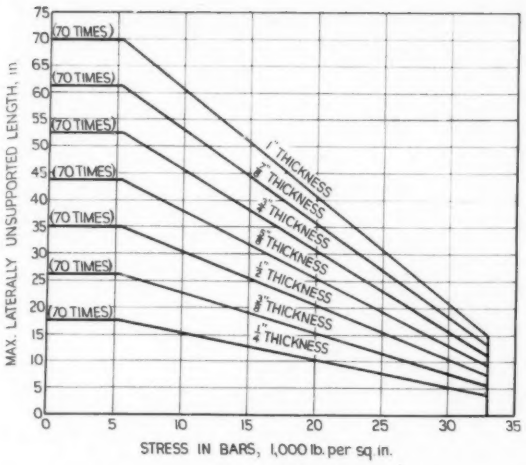


Fig. 7. Maximum recommended laterally unsupported length of mild-steel rack bars

10% of the rack area will be obstructed, increasing the head losses in proportion to the square of the ratio of velocity increase through the remaining flow area, or by a factor of about 1·23. Where severe to very severe trash accumulations are expected, 25% to 50% clogging is often assumed, resulting in an increase of head loss by a factor of 1·78 to 4·0.

Head losses in trashracks are greatly increased when the flow does not enter the racks in a direction parallel to the longitudinal centreline of the bar cross-section. It is very important to prevent such oblique flow by proper arrangement of the intake geometry and rack-bar orientation. Many earlier designs which disregarded this principle resulted in high rack losses and sometimes in a very undesirable condition of non-uniform supply of water to individual passages of a subdivided intake, or to individual turbines. Hydraulic model studies provide very useful guidance for attaining good inflow conditions.

For cases where it is not possible or practical to obtain inflow parallel to the bars, useful information on the correction factor to be applied to the above value of h_r is available in technical literature*.

Rack-Bar Shapes

Rack bars of standard flat rolled steel bar shapes are generally satisfactory for intakes which have been properly designed to produce favourable inflow conditions by use of moderate velocities and a flow direction parallel to the bars. In some earlier designs, round bars and pipes have been used as rack bars. Flat bars with rounded ends, partially streamlined shapes with rounded upstream edge and narrowed downstream end, or streamlined shapes as shown in Fig. 6 have also been used in order to reduce hydraulic losses, especially when flow velocities are relatively high. However, modern hydro-station design practice has largely eliminated the use of special shapes in favour of simple flat bars with rectangular cross-section. Flat bars combine acceptable hydraulic characteristics with superior structural characteristics, assuring good utilisation of material and economy of construction. The use of the more expensive streamline shapes is seldom justified from an economic standpoint. However, the use of bars with upstream edge rounded or both edges rounded may be justified when large quantities are purchased for rack construction.

From the standpoint of hydraulic losses, the bars should be as thin as possible consistent with structural design requirements. However, to avoid damage to bars from handling the racks or from impact of logs and large debris, it is preferable not to use bars less than about $\frac{3}{8}$ in. thick, especially if some allowance for corrosion is desired. For deeply submerged intakes it is desirable to use bars not less than $\frac{1}{4}$ in. thick. It is rarely necessary to use bar thicknesses greater than 1 in.

The depth c of the bars is determined primarily by structural requirements, but to permit raking it should be made sufficient to provide at least 1·5 in. distance from the face of the rack to the horizontal spacers or bracing. The ratio c/t of bars ordinarily used in rack design is between 5 and 12.

Structural Design of Racks

Trashracks and their supporting structures must be designed to withstand the water pressure imposed upon them when the racks become clogged with trash or ice. The choice of design load depends mainly on the severity of the anticipated trash or ice conditions. It also depends on the type and relative importance of the installation, the bar spacing, and the provisions for cleaning. If an effective mechanical trash rake is provided, some decrease in the design load may be justified. For remotely controlled and unattended plants, it is advisable to use higher design loads. Some racks are designed for a difference in head between the two sides of only 5 ft., others for 20 to 30 ft. or more. Loads due to the deadweight of the racks are generally unimportant in their structural design, except when several rack sections are mounted on top of each other.

For intakes where trash or ice conditions are not particularly severe, especially in storage-reservoir projects, a differential head of 5 ft. has proved satisfactory for rack design with normal stresses. Similarly, for those run-of-river projects where trash and ice are not a serious problem and where wide spacing of rack bars can be used, a 5 ft. differential design head is often used. Most of the Tennessee Valley Authority plants in the low-head run-of-river category have

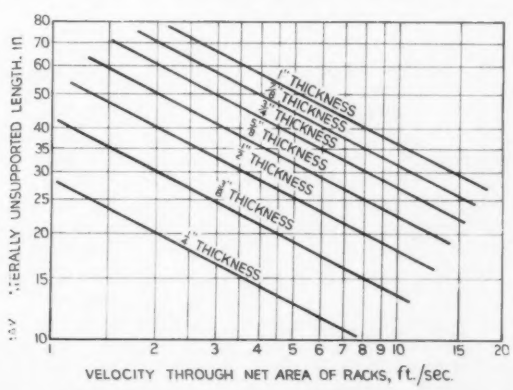


Fig. 8. Maximum recommended laterally unsupported length of steel rack bars to avoid vibration

* E. Mosonyi, "Water Power Development," Volume I, p. 221, Hungarian Academy of Sciences, 1957.

racks designed for a differential head of about 5 ft., with design stresses under this loading not exceeding two-thirds of the yield strength of the material. However, in many run-of-river plants with severe trash or ice conditions and closely spaced bars, differential heads up to the full depth of submergence have been used, although design heads greater than about 30 ft. are exceptional.

Under conditions favouring the formation of frazil ice or anchor ice and subsequent complete stoppage of flow through the racks, the use of the full hydrostatic head is advisable for design, although some designers in Europe arbitrarily limit the design head to about 66 ft. (20 m.).

In hydro-electric projects of the Corps of Engineers, U.S. Army, most of which are low or medium-head developments of large capacity, the racks are usually designed for a differential head of 10 ft. with normal stresses. For low-head intakes the designs often provide for complete stoppage of flow with stresses not exceeding 150% of normal.

In projects of the U.S. Bureau of Reclamation, and also in many privately owned plants, trashrack structures for low-pressure intakes with adequate flow area and racks extending above the normal water line are customarily designed to withstand a differential head of 20 ft. without failure. Higher design heads are occasionally used for racks in low-pressure intakes when necessary, with a limiting value of about 30 ft. for conventionally supported racks. For high-pressure high-velocity intakes, the practice of the Bureau has been to design the trashrack structure to withstand a load equivalent to one-half the head on the racks, with a maximum of 40 ft. The rack bars themselves are usually designed to fail under a load slightly less than that which would cause failure of their supporting structure.

In calculating trashrack loads and stresses, it should be remembered that for partially clogged racks the water-pressure distribution may be assumed uniform, whereas for totally clogged racks it increases with depth of submergence in accordance with hydrostatic distribution.

A useful design formula suggested by the U.S. Bureau of Reclamation and often used in trashrack design based on failure from lateral buckling of the bars assumes that failure stress is reached when the stress in the bar equals the following value:

Failure stress = (yield strength) $\times$ $(1{\cdot}23 - 0{\cdot}0153\ L/t)$

Where: L = laterally unsupported length of bars, in.
t = thickness of bars, in.

If the trashracks are to be designed to permit their sheathing for unwatering the intake, or to support flashboards, the allowable stress with maximum load on the sheathing should not exceed $\frac{2}{3}$ of failure stress. In any event, it is recommended that the maximum laterally unsupported length of rack bars be not more than 70 times their thickness.

Fig. 7, based on the above failure formula, indicates the maximum allowable laterally unsupported length of rack bars made of typical mild steel having a yield strength of 33,000 lb. per sq. in., for any given amount of maximum computed stress in the bars.

The structural design of trashracks should be checked for adequacy against bar vibration induced by the flow and associated shedding of vortices. For any bar thickness and velocity of flow through the racks, there is a maximum safe laterally unsupported length of bars which should not be exceeded. The design chart shown in Fig. 8 indicates the spacing of lateral supports or stiffeners at which the natural frequency of bar vibration in water is 2·5 times the frequency induced by the flow, to assure sufficient safety against approaching resonance and developing vibration of harmful magnitude. The frequency of vortex shedding is based on Strouhal's formula, using a modified Strouhal number of 0·20 to account in part for the influence of the boundary-layer thickness. Fairly good agreement between this chart and actual cases of rack vibration has been found.

Where the trash includes large floating objects such as logs, impact loads may have to be taken into account. An approximate estimate of the impact force can be made, considering that upon impact from a log, the long rack bars undergo elastic deflection in a time interval during which the velocity of the log is reduced to zero. Experience indicates that a time interval Δt of 0·1 sec. may reasonably be assumed. Since the inflow velocity at low-head plants with exposed racks is usually about 3 to 3·5 ft. per sec., an approximate velocity of 3·2 ft. per sec. may be assumed here for convenience, whereby the impact force acting on one or several interacting bars becomes equal to the weight W of the log:

$$P = \frac{W}{g}\,\frac{V}{\Delta t} = \frac{W}{32}\,\frac{3{\cdot}2}{0{\cdot}1} = W$$

This estimate of impact forces is very approximate, but serves to indicate their order of magnitude.

Maintenance of Trashracks

The maintenance of trashracks, apart from the task of keeping them free of trash accumulations which is more of an operating problem, is primarily a matter of protection against rust or corrosion by painting and of repairing bent or damaged parts. Although galvanising has been used in some cases with good results, painting is more commonly relied upon and is often supplemented by the use of cathodic protection.

NOTE: The second part of this article will deal with the design and operation of raking equipment.

(To be continued)

The Jansen Pumped-Storage Scheme. In connection with this article by Dipl.Ing. Gert Naber published in our July and August issues, we regret that on page 319 of our August issue some errors occurred in the list of equipment supplied by the various manufacturers concerned. The correct position is as follows:—

The entire hydraulic equipment, including the turbines, pumps and valves in the power stations and the Rabenleite intake tower, has been constructed by Voith GmbH, Heidenheim. The alternator in Tanzmühle station and one alternator in Reisach power station were built by Siemens-Schuckert AG, who also supplied the electrical automatic gear throughout the scheme. AEG have supplied two alternators in Reisach power station—the second is to be delivered during the present year—and the alternators in Trausnitz power station. This firm has also equipped the 110 kV switchyards at Reisach and Tanzmühle. The transformers, one of which is yet to be delivered, were built by Brown Boveri, who also supplied the 3 MVA alternator in Tanzmühle station.

The chief contractor for the construction works was Kunz & Company, Munich, in collaboration with Hochtief AG and Polensky & Zöllner and other local companies.

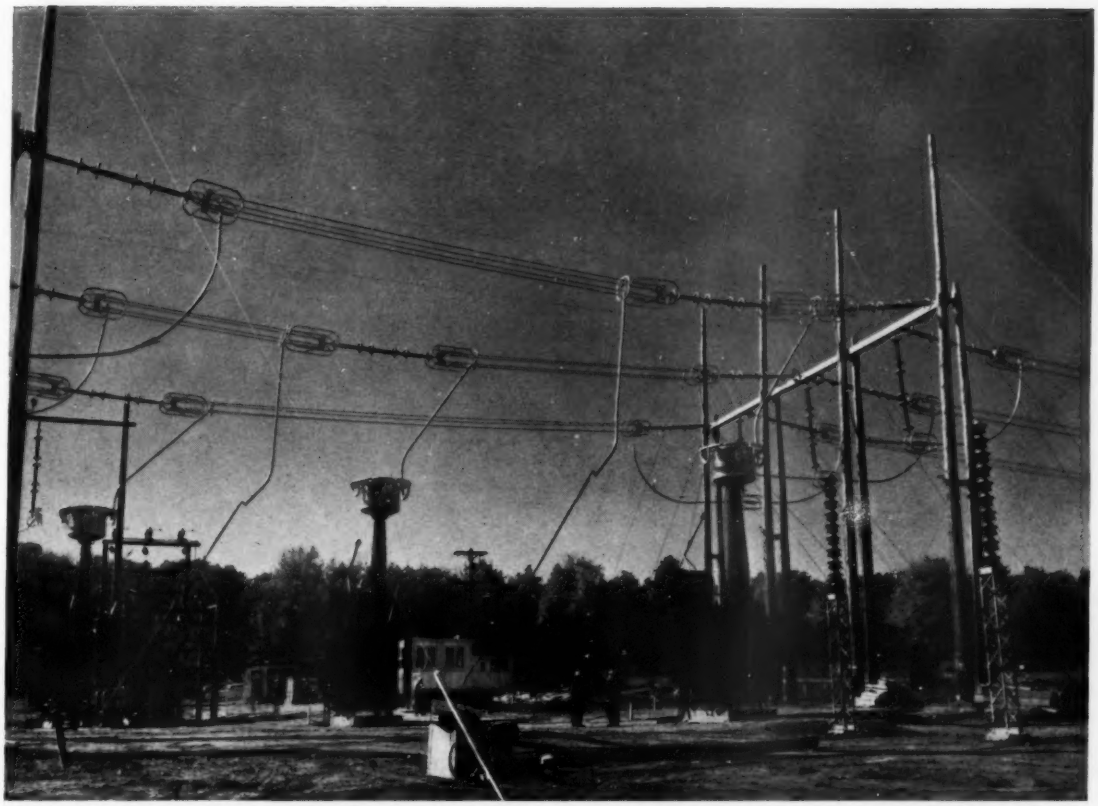


Fig. 1. View of station area showing test transformers, overhead bus work with provision for isolating and earthing each section of transmission line emanating from this area

Some EHV Transmission Problems

An account is given of the experiments being conducted at the Coldwater Laboratory, Canada, to overcome problems associated with EHV transmission such as corona losses, live-line maintenance and radio interference

WITH continuous plans for expansion and generation of power, the Hydro-Electric Power Commission of Ontario, Canada, now requires extra-high-voltage transmission lines to incorporate this new power into the grid system. The new capacity is of the order of 1,200 MW and is to be linked into the system by two 460 kV circuits each about 450 miles long and with an intermediate load centre near the midpoint. It will be mainly used for peaking and is of low load factor; consequently the conductor size is reduced to the point where relatively high surface voltage gradients give rise to corona problems. EHV transmission has its particular problems and the Commission has established a high-voltage experimental laboratory near Coldwater, Ontario, with the primary purpose of providing design information on corona losses, live-line maintenance, radio interference, and generally, establishing an accurate quantitative relationship between conductor gradient and radio interference for the proposed 460 kV lines in Northern Ontario.

Two test lines have been constructed at Coldwater, consisting of three-phase bundled conductors, each about 2,500 ft. long and running in opposite directions from a bank of three centrally located transformers. Each transformer is rated at 1,667 kVA. 15·7/350 kV and is equipped with 345 kV bushings impulse-tested to 1,300 kV. The switching arrangement uses lightweight tubing suspended on hinges from the station test bus. This may be disconnected from the transformer, from the ground, by a special switch stick thus automatically earthing the disconnected phase, as shown in Fig. 1. The blade of the isolator is 4½ in. diameter aluminium tubing and is

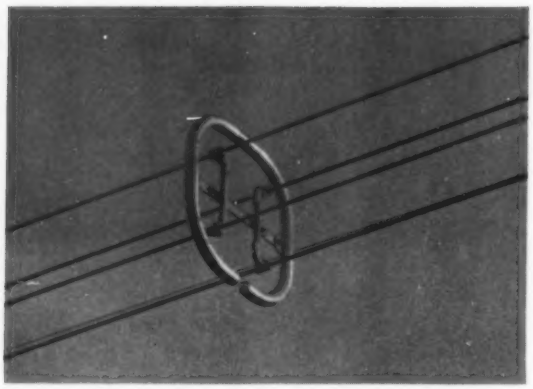


Fig. 2. Adjustable spacer with corona shield

operated by a magnesium rod. The lines consist of bundles of four conductors which are operated at voltages up to 600 kV phase-to-phase. On the north line, each conductor has a diameter of 1·1 in. whereas on the south line each has a diameter of 0·8 in. Since the spans of these lines are relatively short, about 500 ft., spacers are needed at mid-spans only. The loaded tension per phase on the test-line terminations is 20,000 lb. and the conductor loops are of $3\frac{1}{2}$ in. diameter aluminium tubing. Grading rings are liberally used on the conductor hardware. The suspension insulators are of the long-rod type, three per phase with grading rings at each end, as shown in Fig. 3. Four steel earthwires are used, each of 7 strands and $\frac{3}{8}$ in. in diameter.

Corona Losses

A complete analysis of data gathered to determine corona losses on EHV transmission lines has not yet been completed but certain tendencies have been observed. Corona losses on the test lines were higher than those originally estimated, especially in snow, and this can have an effect on the economic design of EHV lines in countries where it snows for much of the time. Test results have shown that losses in heavy snow are similar to those in medium rain. On the south line, tests on the 0·8 in. conductors gave the following typical losses at 500 kV, per three-phase mile:—

19 kW in light rain
110 kW in heavy snow
180 kW in heavy rain.

Live-Line Maintenance

Operating personnel associated with EHV transmission lines have their problems in the maintenance and inspection of live lines. It is a known fact that a lineman, insulated from the tower, builds up a charge, and a sparkover occurs when he approaches the metallic tower. Although no hazard is involved, the lineman experiences an uncomfortable sensation. To avoid this, it is preferred to have permanent contact between the lineman and the tower so as to lower the static current to the minimum perception current. This may be done, for example, by using conducting shoes. At Coldwater, a thorough study was made, with field tests, to determine the feasibility of maintenance on 460 kV transmission lines and to specify the equipment required. An attempt was made to establish conditions for the following:—

1. Safe working clearance on the tower.
2. Leakage and capacity currents at various distances between lineman and conductor, and lineman and tower.
3. The extent of corona on live-line tools.

A metal cylinder was designed of sufficient size to simulate the capacity of an average lineman's body, and electrical measurements were then taken for different positions of the cylinder. The results were tabulated and a formula worked out to give the safe limit of approach,

$$d = a + mg$$

where d = safe limit of approach
a = arbitrary distance to account for lineman's movements while climbing (usually 3 ft., based on experience)
m = safety factor depending on switching overvoltages.
g = switching surge overvoltage equivalent dry-air gap in feet.

Radio Interference

The conclusions drawn from investigating the 230 kV circuits of the Hydro-Electric Power Commission were that, during fair weather, radio interference (RI) was due mainly to conductor hardware noise rather than to conductor noise. The Coldwater project was to determine accurate quantitative relationships between voltage gradient and RI by measurements from the test lines. The conductor sizes of 0·8 in. and 1·1 in. diameter, mentioned previously, were thus

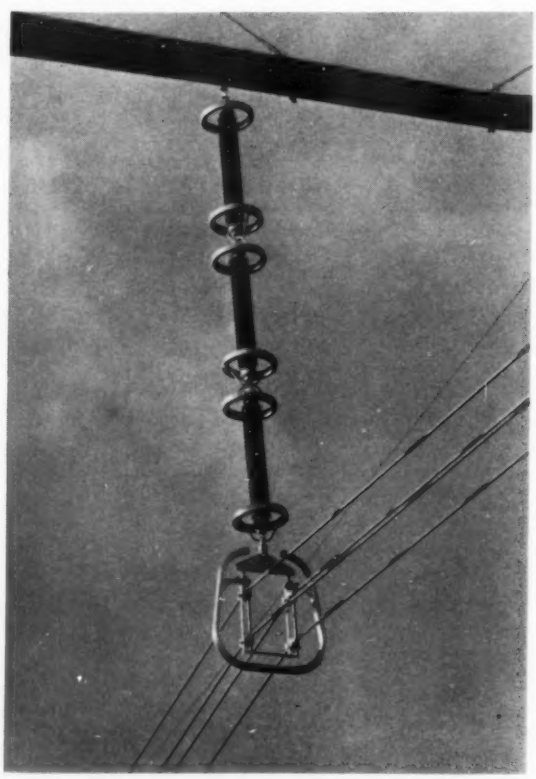


Fig. 3. A four-conductor bundle suspension assembly

chosen to represent the extreme limits within which a minimum conductor size would be found in a four-bundle conductor to give satisfactory RI performance. At 500 kV the 1·1 in. conductor resulted in a gradient of 16 kV per cm. and the 0·8 in. conductors in a gradient of 20 kV per cm. The latter proved quite satisfactory and was quieter when operating at 500 kV than the double-circuit lines operating at 230 kV even though its surface voltage gradient was higher than 17 kV per cm.—the figure that prevalent opinion recommends.

Either of the two test lines at Coldwater, or both, may be connected to the centrally placed transformers. The insulators, grading rings and hardware were so chosen that conductor noise alone would be present. A typical suspension assembly is shown in Fig. 3. The assembly using the rod type insulation was found to be corona free up to 390 kV. Although line spaces were designed to be corona free, the tests showed otherwise and they too were shielded by using 2·5 in. diameter tubing.

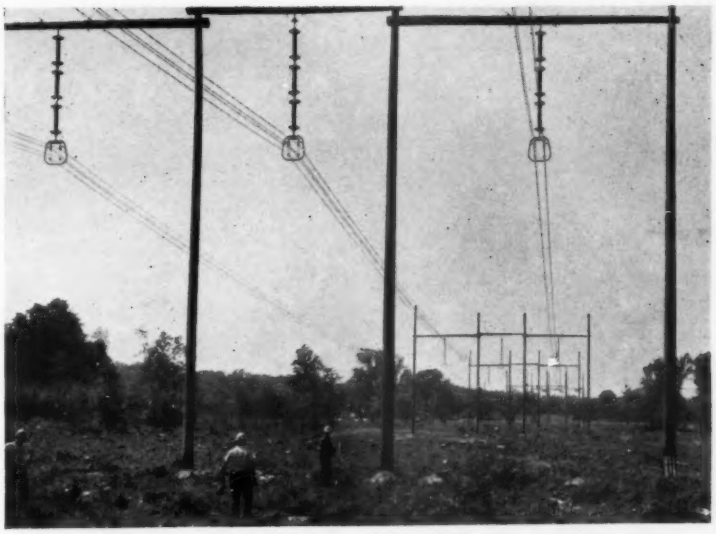


Fig. 4. General view of one section of transmission line. The suspension insulators are of the long-rod type, three per phase, with grading rings at each end

In studying line RI measurements, there is considerable difficulty in interpreting the RI levels obtained on the short line relative to those obtained on the long line, and hence preliminary tests were necessary to find a relationship between short and long lines. These tests were made on long and short sections of an existing line operating at 250 kV. The test results showed that by using terminal impedances, the standing wave patterns of a short test line can be used to determine the uniform noise pattern of a similar long line. This technique was implemented at Coldwater.

The work at Coldwater is still in the preliminary stages and further experimental work will continue in investigating EHV transmission and its associated problems.

Acknowledgment

We are indebted to the Hydro-Electric Power Commission of Ontario, Canada, who have supplied us with the necessary photographs and information to prepare this article.

Symposium on Flow Measurement

A Symposium on Flow Measurement in Closed Conduits has been organised by the National Engineering Laboratory, and will be held at East Kilbride on September 27–30. According to the provisional programme, sessions will be held on the following subjects: Current Meters and Pitot Tubes, Orifice Plates, Venturi Meters, Other Pressure-Difference Devices, Salt-Dilution and Salt-Velocity Methods, Gibson Method, and Special Methods. A total of 29 papers will be presented by British, European and United States authors. Engineers desirous of attending this Symposium should apply to the National Engineering Laboratory, East Kilbride, Glasgow, without delay, as the accommodation is limited.

English Electric's New Division

A new division within The English Electric Co. Ltd. is to be formed to combine all aspects of the Company's hydro-electric engineering at its Netherton Works, near Liverpool. From September 1, 1960, the new Hydro-electric Division will be responsible for all commercial, engineering and manufacturing operations connected with hydro-electric installations, including the design and manufacture of water turbines and alternators, large valves and other ancillary equipment. The manager of the new division will be Mr. J. Gavin Warnock, who is at present manager of the hydraulic department of English Electric's Canadian associate, John Inglis and Company of Toronto.

The division will be formed by moving the staffs of the design, projects and mechanical development sections of the water-turbine department, at present at Rugby, to join the water-turbine alternator section already established at Netherton.

Anglo-French Electrical Porcelain Agreement. Steatite & Porcelain Products Limited, Stourport-on-Severn, announce that an agreement has been concluded with the French manufacturer of electrical porcelains Compagnie Générale d'Electro-Ceramique for full technical collaboration, including exchange of patent rights. At the same time, Steatite & Porcelain Products have become selling agents in Great Britain for the products of Compagnie Générale d'Electro-Ceramique, which company will now represent Steatite & Porcelain Products in France.

Wakefield Castrol Renamed. To simplify the work and identity of the Wakefield Castrol Group, which embraces 24 companies throughout the world, C. C. Wakefield & Co. Ltd., which was founded in 1899, is to change its name to Castrol Limited.

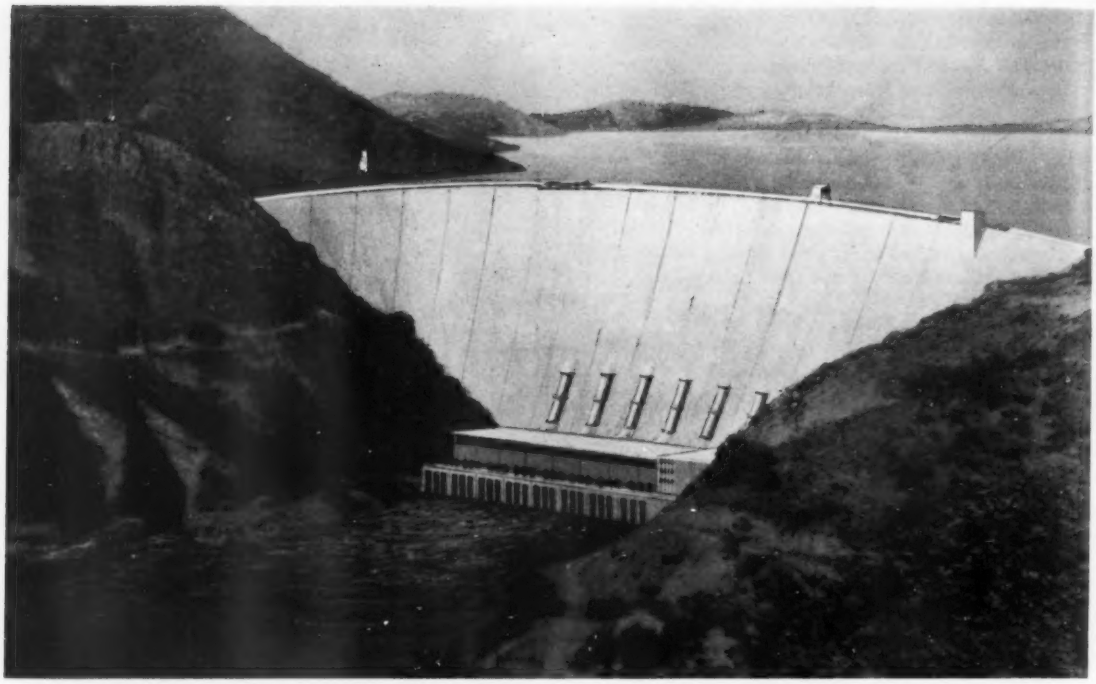


Fig. 1. Artist's sketch of the completed Bhumiphol dam showing the penstocks, power house and spillways

The Yanhee Multipurpose Project

The significance of this important project in the Kingdom of Thailand is explained and its main features are described

By BERNARD L. ROBINSON*

ONE of the largest hydro-electric projects in Asia is now under construction on the Ping River in north-western Thailand, about 420 km. north of Bangkok. Known as the Yanhee Multipurpose Project, it will, when completed, furnish much-needed power to Bangkok and to about 7,500,000 people in 33 Thai provinces, plus additional benefits in the form of improved flood control, irrigation and navigation. The entire project, including the dam, power plant, and transmission lines, is under the able direction of Mom Luang Xujati Kambhu, Director General of the Royal Irrigation Department of the Kingdom of Thailand, one of the country's leading citizens and one of its most prominent engineers. Current plans call for construction in five stages, with completion of the first stage in August, 1963.

The dam, to be called the Bhumiphol dam in honour of the reigning King of Thailand, will be a 154 m. high concrete arch structure approximately 467 m. in length at roadway level. It will be about 52·2 m. thick at the base and about 6 m. thick at the crest. The power plant will ultimately house eight 70 MW turbine generators, giving a total installed capacity of 560 MW capable of producing 1,944 GWh annually. The reservoir, 100 km. long, will have a maximum storage capacity of 9,890,000 acre-ft., thus providing water for the dry-season irrigation of 920,000 acres and making possible agricultural development of an additional 320,000 acres. Release of the normally impounded waters from the Yanhee reservoir will improve navigation along the Ping and Chao Phya Rivers.

The size of the reservoir will enable it to impound the flood waters from extra heavy rains; however, to protect the dam the spillways will be adequate to discharge floods estimated to occur once every thousand years.

While the initial project contemplated the construction of a 138 kV transmission system, subsequent studies indicated that more economical distribution would be achieved by using 230 kV. The current plan, therefore, is to construct a 465 km. line of double-circuit steel towers from Yanhee to Bangkok, with only one circuit to be installed during first-stage construction. Three substations at Bangkok will be connected by an additional 20 miles of 230 kV lines. In addition, substations are also planned at Angthong and Nakhon Sawan. Bangkok and about 13 other communities will be served initially by these substations. Secondary transmission will be at 69 kV.

* Major-General, U.S. Army, Ret., Vice-President, Sverdrup & Parcel International, Inc.

Organisation of Project

Financial arrangements for the Yanhee project were completed when the International Bank for Reconstruction and Development granted a loan of $66 million to the Kingdom of Thailand, which in turn agreed to pay the remaining $35 million of the estimated cost of the first stage. The Royal Irrigation Department is directing the design and construction of this project. The Department entered into a contract with Sverdrup & Parcel International, Inc., for consulting services covering the design, procurement, and supervision of construction of the project. Design of the structures and the procurement of government-furnished equipment and materials were subcontracted by Sverdrup & Parcel to Engineering Consultants, Inc., of Denver, Colorado, and this work is being done under the general supervision of Sverdrup & Parcel International, Inc. In addition, the Department's Director General, M. L. Xujati Kambhu, appointed the following International Board of Consultants:

Prof. R. E. Davis, Chairman, Berkeley, California, U.S.A.
Mr. C. E. Blee, Pasadena, California, U.S.A.
Mr. E. B. Burwell, Jr., Upperville, Virginia, U.S.A.
Mr. Henri Gicot, Fribourg, Switzerland.
Mr. F. Vogt, Oslo, Norway.

Construction of the dam, spillways, power-house foundation, and power-house superstructure, to house three units, was put out to bid on a world-wide basis. Bids were opened in Bangkok on April 14, 1958. Seven bids were received, and bidders included firms from Italy, Germany, Denmark, Japan and the United States, as well as a French and a Danish firm bidding jointly. Award was made to the low bidder, a joint venture of two firms, Brown & Root, S.A. and Utah International, Inc. The contract was signed on July 31, 1958, and notice to proceed was given on October 20 of the same year.

Bidders were permitted to submit proposals either on a lump-sum basis or on a target estimate basis with bonus and penalty provisions. Most firms, including the successful bidder, selected the latter type of contract. Using this, the contractors quoted unit prices on about 150 items with estimated quantities, and on certain additional lump-sum items. The bid total was determined as the sum of the unit prices multiplied by estimated quantities, plus the lump-sum items. The

Fig. 2. Regional map of Kingdom of Thailand

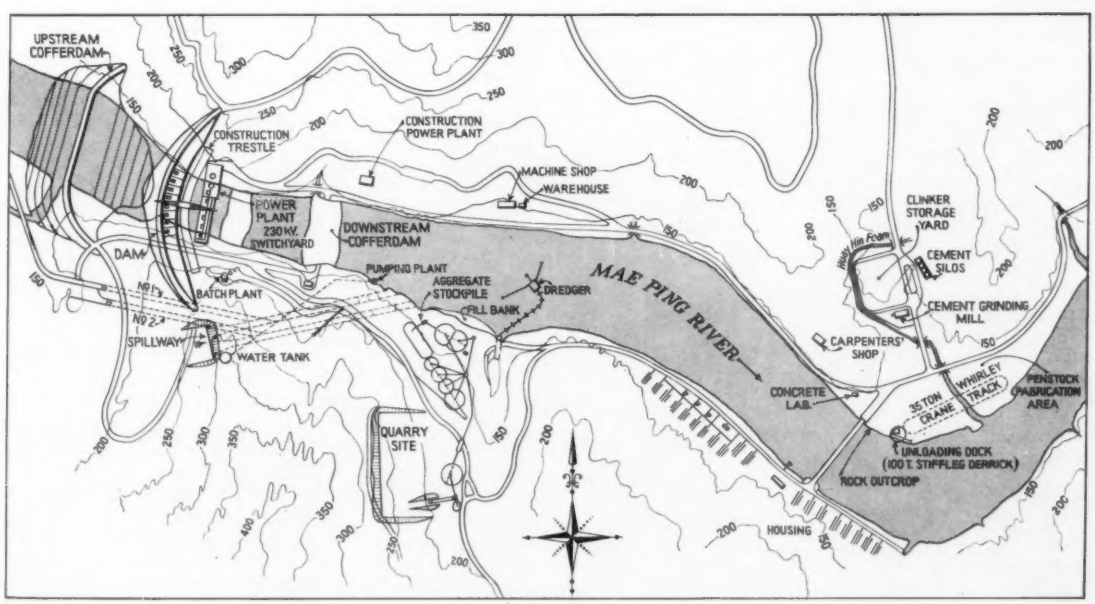


Fig. 3. A sketch plan of the dam site area on the Mae Ping River

Fig. 4. Upstream view of Bhumiphol dam site showing the diversion tunnels being excavated in the centre. The scaling of the slope at the left centre is for aggregate quarry site

provisions for bonus and penalty were as follows:

(a) *For bonus.* If the work is completed for less than the target estimate the contractor will be awarded a fixed percentage of this reduction. In addition, if the contractor completes the construction in less than the contract completion time, he will be awarded an increase in fee proportionate to the time saved.

(b) *For penalty.* In the event the final cost is greater than the target estimate, or if the contract completion time is overrun, there will be a corresponding reduction in the contractor's fee.

In general, the remaining provisions of the contract conform to standard cost-plus-fixed-fee contracts in the United States. Contract completion time is 1,765 days from receipt of notice to proceed, which places the first-stage completion date in August, 1963. There is a provision in the contract, however, which provides for extension of this time in the event of delays beyond the control of the contractor.

By mutual agreement between the Yanhee Electricity Authority and Bangkok's Metropolitan Electric Authority, Yanhee officials are giving first priority to the construction of the "Bangkok Loop" tie lines, so that this distribution system may be used when the Metropolitan Electric Authority completes construction of a 75 MW steam plant in the Bangkok area early in 1961. It is worth mentioning that Brown, Boveri and Co. Ltd. have been awarded the contract for the construction of the Bangkok Loop. The date of completion is expected to be early in 1961.

Contracts for the following principal items of materials and equipment have been awarded to date:

Turbines: Hitachi Ltd. of Japan.

Generators: Allgemeine Elektricitäts Gesellschaft, Berlin, Germany.

Reinforcing steel: P. A. Learmond Co. Ltd., London, England.

Refrigeration equipment: Grasso's Koninklijke Machine Fabrieken of Holland.

Preliminary Construction by Royal Irrigation Department

Much preliminary construction work was completed by the Royal Irrigation Department's own forces before the contractor's arrival at the site. Access roads, offices, and camps were built, and two pilot tunnels were driven through the right bank. These pilot tunnels are now being enlarged for use as diversion tunnels during the construction of the dam. The downstream half of these tunnels will become part of the spillway tunnels when the project is completed.

The construction of the Yanhee project requires more cement than could be supplied from Thai sources existing before 1958, and the Thai government aided in the formation of the Jalaprathan Cement Company to build a cement mill near Takli, about 140 km. north of Bangkok and about 300 km. from Yanhee. The plant, which began work in July, 1958, produces a cement clinker which is transported by truck to the Yanhee site where the company will build a mill capable of grinding 300 tons of cement per day. Cement meeting job specifications will be stored in silos built by the Royal Irrigation Department.

Heavy equipment purchased outside Thailand will be brought by barge to the project site during the monsoon season when the river is at its highest. The Irrigation Department is already constructing dock and crane facilities to handle this equipment.

Current Construction

The contractor has given first priority to the completion of the diversion tunnels, to divert the river late in 1960. Completion of the cofferdams is expected after the 1960 monsoon season. The contractor has built a steel-girder access bridge across the Ping River below the downstream cofferdam and is developing a quarry site near the dam on the right bank. Various shop buildings have been constructed and a diesel power plant has been installed.

The presence of highly permeable sand, gravel, and heavy boulders, as determined by probings and borings along the centreline of the upstream diversion cofferdam, has raised problems in the design of this cofferdam. Highly permeable sand and gravel also underlie the ends of the upstream and the axis of the downstream cofferdams. The contractor is solving the problem of a below-stream cut-off wall in those areas free of boulders, by using a single line of sheet-steel piling which will extend to bedrock along the axes of the upstream and downstream cofferdams. In the boulder area, along the axis of the upstream cofferdam, a cut-off wall of H-beams with sheet piles welded to both flanges will be used. When these are in place, the area between the two lines of sheet piles will be blown clean and sealed with concrete. An earth-and-rockfill, with impermeable clay core, will be placed above the sheet-pile cut-off walls. The finished upstream cofferdam will measure approximately 50 m. from the base of the cut-off wall to the top of the fill. A system of wellpoints and pumps will handle any seepage that occurs. The complete diversion system has been designed to divert a 25 year flood safely.

After a careful analysis of methods of placing concrete, the contractor has elected to use a steel trestle and three cranes. The trestle, designed and fabricated by Stupp Bros. Bridge & Iron Co., of St. Louis, Missouri, will be built to the top of rail elevation (195 m.) and a low gantry crane will be used initially so that the rotating-pin elevation will be at 111·6 m. As the dam rises, a gantry tower will be added to raise the rotating-pin elevation to approximately 250 m. The elevations given are referred to mean sea level. On the axis of the dam the river bed is at an approximate height of 137 m. Lowest bedrock is encountered at an elevation of 107 m. The cranes, furnished by the American Hoist and Derrick Co., of Fort Wayne, Indiana, are rated for 25 U.S. tons at a 120 ft. reach, or for 10 U.S. tons at 200 ft. Two-hundred-foot booms will be used, with provisions for attaching an additional 20 ft. jib boom.

Two, four, and eight cu. yard concrete buckets will be used. The equipment layout is planned to make the rehandling of these buckets necessary for only a relatively few yards of material at either end of the dam. Concrete will be mixed in three mixers, each of 4 cu. yards capacity, and batching and ice-making plants will permit a maximum production of 4,000 cu. yards of concrete per day. A mixture of river and manufactured sand will be used, the manufactured sand supplying certain deficiencies in the river sand.

Need for the Project

Consumption of electricity has been low in Thailand, and as late as 1956 the annual *per capita* use was only 9 kWh. Until recently the total generating capacity in use in the Thai public utility systems amounted to a little over 100,000 kW, all generated by steam and diesel units. Approximately 60,000 kW of this total was centred in the Municipal and Government systems in the City of Bangkok. Of this, 21,000 kW was generated by four diesel plants, and the remainder by two steam plants which work at low and inefficient pressures. New diesel units were recently installed, raising the total capacity in Bangkok by about 17,000 kW. The new 75 MW steam plant mentioned above will serve the metropolitan area until the completion of Yanhee, at which time it becomes available for integration into the system.

The demand for electricity has greatly exceeded the capacity of the public-utility systems, and restrictive measures have been used to reduce the demand for power. These measures have included temporarily lowering the voltage, blacking out parts of the city, arbitrarily limiting new loads, and shutting down certain operations at peak periods. Consumption has also been limited by the low capacity of household meters, by rates which rise as consumption increases, and by the lack of an adequate electrical distribution system in the Bangkok area. This situation has been only partially alleviated through the private installation of over 50,000 kW of diesel-generated power by industries, hotels and theatres.

Expansion of Thailand's thermal-power generating capacity is severely limited by supply, transportation and cost factors. The country's forests are rapidly being depleted for conversion to charcoal. Sizeable

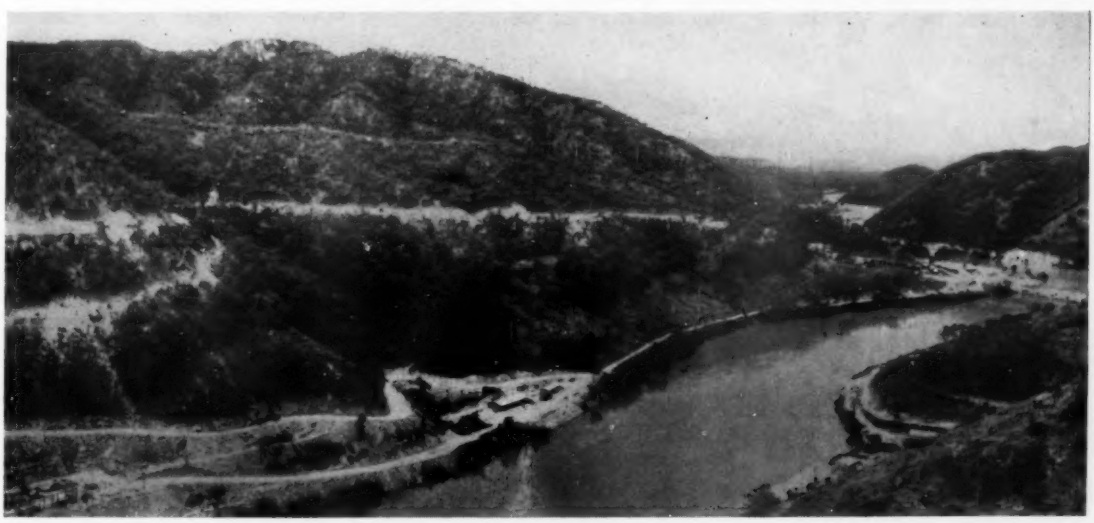


Fig. 5. Downstream view of Bhumiphol dam site showing construction power plant being built in foreground

Fig. 6. Construction of cement storage silos by Royal Irrigation Department

lignite deposits around Mae Moh (120 km. north of the Yanhee dam site) are mined and used principally by steam-generator power plants. The output of these mines will be expanded to provide fuel for a 12 MW steam power plant now being built at Mae Moh, and for the 75 MW plant now under construction in the Bangkok area. The Mae Moh plant will provide power at Yanhee during part of the construction period and, later, will be added to the Yanhee distribution grid. At present, an average of about 400 tons of lignite must be hauled into Bangkok by rail daily for power generation, and this figure will increase significantly when the new Bangkok power plant is completed. All petroleum products used in Thailand must be imported, thus representing both a cost and a transportation item.

In view of the foregoing, an alternative method of power generation is needed in Thailand. The Royal Government has been much aware that adequate power is a prerequisite to the economic development of this kingdom of 24 million people, and cheap hydro-electric power has long been the dream and ambition of Thai leaders. In 1952 the National Economic Council made a survey to determine the existing and potential electric loads in the Bangkok-Thonburi area, and in 27 provinces in the central plain. Recently, the survey was brought up to date and six provinces in north-western Thailand were added.

In stimulating the economic development of the country, however, power is not the only problem to be solved. Control of the river levels and the impounding of water are also major problems. Thailand's economy is primarily based upon agriculture, much of which depends upon extensive irrigation. River levels are unpredictable because of the variations in yearly rainfall, and flooding occurs regularly, occasionally destroying the entire rice crop. Ordinarily, about 8,000,000 acres require replanting annually with a fast-growing seed of inferior quality and yield. The extensive dry weather following the yearly monsoon makes irrigation a necessity, and if the rainfall is less than normal a critical agricultural problem results. The provision of an adequate supply of water for irrigation and the reduction of flooding will have a marked and beneficial effect upon the economic growth of the country.

Since Thailand's rivers are its most natural highways both for travel and commerce, control of river levels is desirable for development of a more dependable and useful river navigation system.

Advantages of Yanhee Site

Having determined the need for a hydro-electric project, the Government of Thailand requested the Royal Irrigation Department to prepare a comprehensive engineering report on the location and design of a power plant and power distribution system. This report was completed in 1952.

In selecting a site for the project, consideration was given to the three main river systems in Thailand, each of which runs roughly north and south: the Klong in the West, the Chao Phya in the Central area, and the Mekong in the East. The Chao Phya was selected as the most desirable river because it is the most extensively used river in Thailand, it is the longest river solely within Thai borders, and the river and its four tributaries drain 33 of Thailand's 71 provinces. This area includes 9,500,000 people (about 40% of the population) and the major portion of Thai agriculture, industrial facilities, transportation, banking and trading establishments. Clearly, then, a single hydro-electric development on this river would have the greatest economic effect for the greatest number of people and for the largest possible geographical area. The Klong, and especially the Mekong, rivers present excellent possibilities for additional hydro-electric development, but border problems are involved here and these projects would produce smaller initial economic benefits for Thailand.

Of the four great tributaries of the Chao Phya rising in the northern mountains (the Ping, the Wang, the Yom, and the Nan), the Ping River was selected as the most desirable tributary. On this river the Yanhee area was selected as no other area seemed to have both the desired capacity and the favourable geological conditions. Four possible sites were investigated in the Yanhee area, but the site selected at Khao Kaew is believed to be the most desirable for any height of dam, and to be topographically and geologically suitable for a concrete arch dam. At this site the river flows through a rocky gorge where foundation conditions are expected to be excellent. Also, a large storage reservoir is possible at this point which will provide enough water for power, stream regulation, navigation, and irrigation.

Flood Control

Disastrous floods such as the ones which occurred in 1942 and 1959 can destroy crops on as much as 100,000,000 acres of land in the central plains. Although the construction of the Yanhee project will not prevent all the floods in the central plains, as there will be uncontrolled flows from the other tributaries of the Chao Phya, nevertheless, there will be a substantial reduction in flood damage because of the Yanhee construction. Flood damage along the Ping River below the dam will be virtually eliminated.

Irrigation

Many irrigation canals and storage and water-control works have been built in the plains areas of Thailand. In August, 1956, the Royal Irrigation Department completed construction of the Chainat dam on the Chao Phya River, 160 km. north of Bangkok. Located about 260 km. south of the Yanhee site, the dam with its associated canals (called the Chao Phya Irrigation Project) will eventually provide irrigation for 10,000,000 acres of land, and annual rice production should be increased by 320,000 tons annually. The Chainat, however, is a low dam, raising the river level by only 11 m. providing irrigation for only 6 or 7 months of the year, and affording little flood protection. The regulation of the river flow by Yanhee will have a very beneficial effect on this irrigation project.

Yanhee will have a threefold effect on agricultural production in the central plains: first, by increasing the production of new crops during the dry season; second, in dry years, by eliminating rice-crop losses during the early growing season; and third, by reducing crop losses from floods. In the Chao Phya area, dry-season crops such as beans, corn, peanuts, and sugar cane are now grown on about 6,500,000 acres. When sufficient irrigation water eventually becomes available, a total of about 37,000,000 acres can be used for these crops. Five million acres will be affected annually by the Yanhee project through the elimination of water shortages caused by short monsoon seasons. These results should directly increase Government revenues substantially; export duties and other taxes on rice amount to about 40% of the crop value.

Flood-control benefits will also accrue to some 24,000,000 acres of land in the Kamphaeng Phet area, about 110 km. south of the Yanhee project, when irrigation works and protection are constructed.

Navigation and Recreation

The main transportation arteries in the northern and central parts of Thailand are the Ping and the Chao Phya Rivers. However, traffic is stopped or restricted during the dry season. The traffic on the Ping River is chiefly logs floated during the flood season, but numerous sand bars prevent heavier traffic. Substantial benefits to navigation on the Chao Phya River can be expected to accrue below the junction of its four great tributaries at Nakhon Sawan where the channel is better maintained and river traffic can be expected to increase. Only the southern 120 km. of this river is navigable during the dry season. When the Yanhee project is completed, navigation will be possible on the entire river throughout the year. Agriculture will also benefit from this improved navigability since crops deteriorate in storage during the dry season when barge traffic is not possible.

The reservoir will create a lake approximately 100 km. long which will provide a great potential for recreational facilities including boating, swimming, fishing and camping. The reservoir area, located in the wooded hills of North Thailand, is beautifully scenic and should attract many visitors.

Project Planning and Financing

The Government of Thailand used the comprehensive report prepared in 1952 by the Royal Irrigation Department as a basis for requesting international assistance in financing the Yanhee project. In 1952 application for a loan was made to the International Bank for reconstruction and Development. The Bank requested that a suitable independent agency make a thorough technical review of the Department of Irrigation's report. The selection of the United States Bureau of Reclamation was approved by the International Bank in 1953 and following a substantial investigation and evaluation, the Bureau submitted its analysis report dated December, 1955.

In its report, the Bureau recommended construction of the project at the earliest practicable date. The Bureau recommended an initial development of: an arch-type concrete dam, rising 154 m. above the foundation at the Khao Kaew site on the Ping River; an adjacent power plant containing two 70 MW generators with minimum provisions for future installation of six additional 70 MW units; two 138 kV single-circuit transmission lines from the dam site to Bangkok; one via Tak, Phitsanulok, Nakhon Sawan and Lop Buri, and the other via Tak, Kamphaeng Phet, Nakhon Sawan and Suphan Buri; and substation facilities to supply power to Bangkok-Thonburi, and 11 intermediate points. In addition, the Bureau recommended full development of the project at a maximum rate consistent with growing power requirements and economic feasibility. This will necessitate the installation of the remaining six generators and the construction of transmission and substation facilities to serve 22 additional load areas.

As was indicated earlier, the International Bank, acting upon the recommendations of the Bureau of Reclamation, granted the loan. The following factors, developed in the course of various studies of the project, were considered in the final decision.

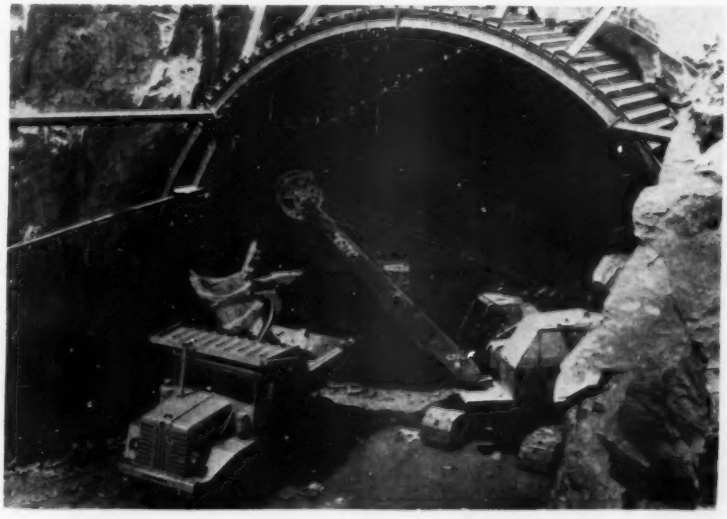


Fig. 7. Mucking operations at portal of 13·2 m. diameter diversion tunnel

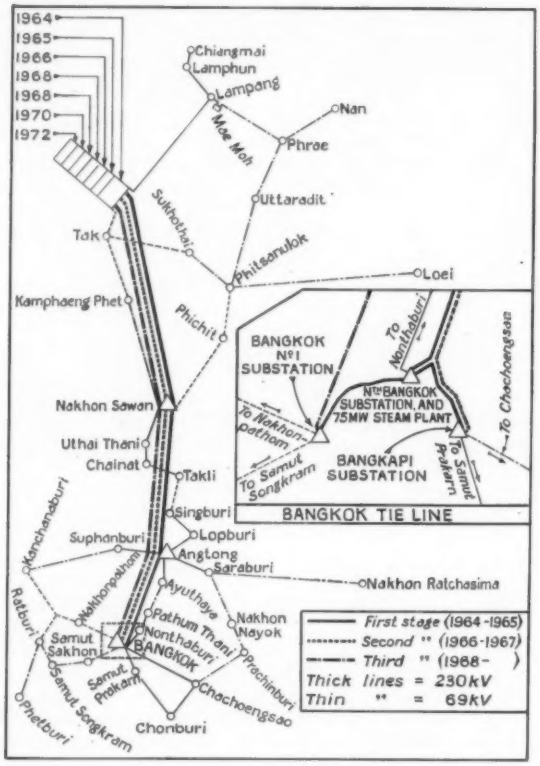


Fig. 8. Development schedule of 230 kV transmission system

Load estimates made by three independent agencies confirmed not only that a rapidly growing demand will continue until the time that Yanhee power is initially put on the line, but also that the revenue potential will be more than adequate to amortise the investment, together with interest throughout the loan period. Until 1963 when Yanhee power is expected to be on the line, the present growth in demand should continue and the maintenance of power restrictions can be expected. Power from the 75 MW steam plant under construction in Bangkok is expected to be available early in 1961.

A conservative figure of 45% load factor in Bangkok was used in the analysis. In the provinces a 40% load factor was used for the first 8 years' operation when it increases to an average of 45%. Little seasonal variation in power use can be expected in Thailand.

An analysis of the probable power demand in 1963 indicates that an industrial load of 17,000 kW currently supplied by privately owned diesel units will be added to the public-utility system, and the load in 11 communities serving a population of about 3,000,000 in the provinces will add an additional 17,500 kW by 1963. Adding to these the 113,000 kW utility load in Bangkok, there will be a requirement in excess of 140,000 kW. It was on this basis that the initial construction of two units was adopted. Subsequent studies, however, indicate the probability of an even greater load growth, justifying an accelerated schedule of installation for the third and succeeding units at Yanhee. The problem here will be one of financing.

Conclusion

In constructing Yanhee the Government of Thailand has undertaken the largest single project of its kind in the long history of its people.

The project is a bold stroke towards the accelerated economic development of the nation, and will eventually serve the power needs of nearly 40% of the entire population. Cheap power will attract industry and additional benefits will accrue to the central plains area in the form of reduced seasonal flooding, improved year-round irrigation, an increase in irrigated areas, and increased river traffic.

Statistics

Some interesting statistics relative to the project appear below:

Personnel currently on the job

Thai: 2,300.
Non Thai: 29 (consulting engineer), 45 (contractor).

General data

Cubage in the dam: 990,000 cu. m. of concrete.
Amount of rock to be excavated at dam site: 394,000 cu. m.
Amount of rock to be excavated for diversion and spillway tunnels: 212,000 cu. m.
Length of reservoir: 100 km. approx.
Miles of road to be rebuilt: 300 km.

Material quantities

Amount of cement to be used: 248,000 tons.
Concrete in power house: 58,000 cu. m.
Amount of reinforcing steel to be used: 8,900,000 kg.

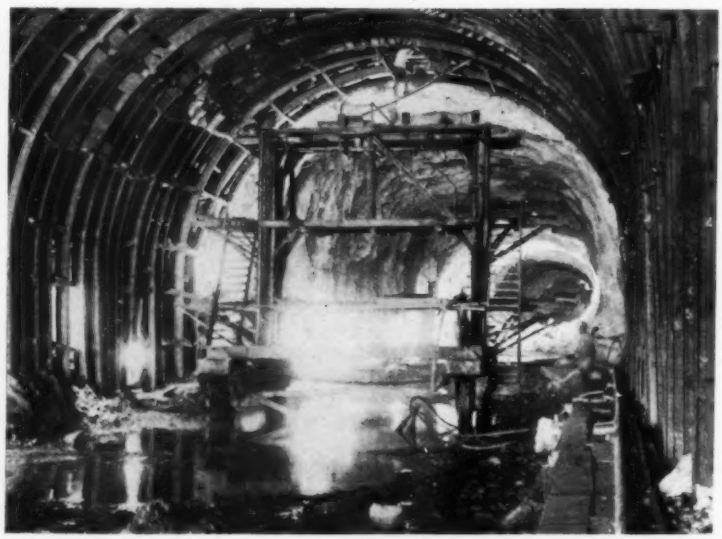


Fig. 9. Placing lagging from drilling jumbo in diversion tunnel No. 1

CIGRE, 1960

A commentary on the proceedings of the 18th meeting of the International Conference on Large Electrical Systems held recently in Paris

THE 18th meeting of the International Conference on Large Electrical Systems was held, as usual in Paris, during June this year, and attracted even more delegates than before, with some 2,000 people being present.

Generators

In the session on generators the main questions discussed concerned definitions of the systems of excitation and the qualities required from them, coupled with the allied question of excitation by means of rectifiers. The discussions included direct current, dielectric tests, asynchronous operation of turbo-alternators, choice of power factor for large alternators, and the possibility of providing reactive power by the use of synchronous machines.

On the first question, it was soon apparent from the papers and the discussions that the benefits to be obtained from the use of semiconductor and similar types of rectifier was that particularly rapid response could be obtained, thus providing excellent control qualities. There was some discussion, without any particular conclusion being reached, on the "yard-sticks" to be applied to measure the characteristics of one excitation system as compared with another. Advantages of semiconductor rectifier systems included the almost complete abolition of maintenance, and the possibility of obtaining higher voltages—higher than those that could conveniently be made available with rotating machinery—with consequent improvement in economy and efficiency. Some fears were expressed, however, that there might be unknown factors which might militate against the successful operation of static rectifiers when faults such as short-circuits or falling out of step caused transient conditions. Other engineers thought that protective gear could be evolved to prevent either maloperation of the machine itself or damage to the rectifiers.

On the question of the testing of generator insulation, it seemed from the papers and discussions that there is still some doubt as to the validity of the various criteria recently proposed to apply not only to the quality of new insulation but to the maintenance of sound insulation throughout the life of the machine. High-voltage direct-current tests provoked much discussion, particularly on the equivalence of these tests with a.c. tests. Several speakers thought that great care must be taken when using high-voltage d.c. tests to ensure that these tests were not taken as the sole means of evaluating the qualities of the insulation. The leakage current ascertained during these tests could be of the greatest significance, but it seemed difficult to extrapolate these tests on an Ohm's law basis.

One of the advantages of the CIGRE conference is that it brings together a very large amount of test information on subjects such as these; and this occasion was no exception, since the papers and discussions produced a mass of statistical data on generator insulation testing, which, when digested by the time the next CIGRE conference comes round, may give an authoritative pointer to the best form of generator tests.

The asynchronous operation of turbo-alternators was the subject of a paper from Britain in which it was shown that it is quite possible to run large steam-turbine units as asynchronous motors, but it is unlikely that water-turbine machines of any size would be operated in this way. Nevertheless, hydro-electric engineers may care to note that their steam-station colleagues are experimenting in this field and have solved the problems of excessive heating, control under all operating conditions, and other difficulties that might be expected under these unusual circumstances. It was thought economic from the point of view of a large interconnected system to operate on occasion with certain machines relegated to the position of synchronous condensers.

There was some discussion also on the choice of value of short-circuit ratio for various types of generator. It was stated that for thermal generators there was a tendency to reduce the short-circuit ratio, and the value of 0·5 was nowadays considered as normal, with lower values occasionally being found. For hydraulic generators, however, the choice of a high value was traditional, but it was thought that it could only be justified in special cases, particularly when it was necessary to maintain long lines operating on no-load conditions at full voltage, in order to avoid auto-excitation under these conditions. Some engineers pointed out that the quality of the voltage regulators in use today makes it possible to obtain very high degree of natural stability under any conditions.

In regard to the operation of alternators under asynchronous conditions, it was said that in various countries, particularly in the U.S.S.R., Poland and Rumania, the rapid coupling-in of hydro-electric generators was common practice. The unexcited generator was brought to asynchronous operation near to synchronism, and was then excited. This method was said to be useful in connection with low-head hydro-electric sets with a low inertia, and was also used in France for the submerged bulb-type generators. It simplified automatic hydro-electric station operation, but naturally caused some disturbances on the system, especially in the case of low-reactance generators.

Transformers

The transformer sessions were held under the chairmanship of Mr. E. T. Norris, of Ferranti Limited, Great Britain, and concerned themselves with three preferential subjects for discussions: problems related to large autotransformers, dielectric tests, and oil preservation and associated problems.

It soon became obvious that autotransformers are used to a rapidly increasing extent in almost every country to tie together the large overriding networks which are superimposed on the regional power pools. The first point concerned the necessity or otherwise for a tertiary winding on such transformers, and it was thought that this winding was required even if no external circuit was connected to it, in order to eliminate telephone interference. Some engineers said that telecommunication circuits experienced considerable disturbance when the delta stabilising winding on autotransformers was opened, but others thought that earthing and suitable connection arrangements for all the transformers in a particular substation could be so arranged as to eliminate the need for tertiary windings, which would, naturally, reduce the cost of the transformer. Nevertheless, it was pointed out that the tertiary winding does provide a means for maintaining the zero-sequence reactance of the system at the low value which may be required to satisfy the conditions of an effectively earthed system.

Another point which was raised in the autotransformer discussions was the need for surge arresters at the intermediate-voltage tapping point, since the rise in voltage caused by perturbations on the high-voltage system might cause unpredictable disturbances at the intermediate voltage connection. These arresters, however, if fitted, might lead to a requirement for special impulse testing processes not now generally employed.

It was seen that transportation limits, at the present time, allow for transformers of up to 300 MVA to be taken to site, both three-phase and single-phase, and the use of banks of this size has already been decided upon in several countries.

It was made clear, in the discussions, that there is no definite upper limit to the transformation ratio that can be reached with autotransformers, and this design remains advantageous as the voltage increases, when compared with a two-winding unit in regard to transportation weights and dimensions for a given rating, and also in relation to reduction in losses.

On the question of dielectric tests, the replacement of the sphere gap by crest voltmeters was suggested by a number of engineers. The sphere gap is still generally used in Europe and is the only international standard for reference, but is cumbersome and requires a great deal of room in the test area. The replacement was desired, it seemed from the discussion, more from the point of view of convenience than for improvement of measurement technique. Another point raised under the heading of dielectric tests concerned complementary switching surge tests, which some thought to be of no value in the present state of industrial frequency testing, while others thought that it would have some usefulness if the test value were considerably reduced. It was pointed out that in every country different testing conditions are applied, and not all authorities accept the chopped-wave test, mainly for two reasons: first, the small increase of stresses which it produces in anti-resonant windings; and secondly, its diminution in value due to the measures taken to avoid flashover conditions in substations. It seemed on the whole that engineers were satisfied with the conventional industrial frequency tests, and that any proposals for further tests which were claimed more nearly to approximate service conditions were not required.

There seemed a general desire to adopt any device which would tend to reduce the pollution of transformer oil and inhibit its oxidation, as these two aspects of transformer-oil operation appeared to be universally troublesome. There was no precise agreement, however, on the type of device most suited to prevent this trouble. Conservators closed by a flexible butyl membrane, and the nitrogen-gas cushion device, seemed to be the best answers to this problem, in the opinion of the majority of speakers.

Circuit Breakers

In the circuit-breaker discussions, one of the problems seen to be emerging as networks increased in size is that of interrupting what are known as "kilometric" faults. The kilometric fault is defined as one that occurs within a short distance in an overhead transmission line which is part of a large network, and where the characteristic of the fault conditions is that there is a very quick rate of rise of recovery voltage. One method proposed to deal with kilometric faults was to connect a resistance, of relatively low value (for example, 500 ohms) parallel to the circuit-breaker terminals, or to each element of the breaker. It was agreed that the manufacture of these resistances would present certain problems, mainly due to the reduced dimensions which would be necessary. However, such resistances have in fact been successfully designed and applied.

The measurement of post-arc current has been the subject of research work in a number of countries, and a great deal of information from Germany, France, Switzerland and Holland was presented to the conference showing the results of some of these studies. Restrikes can be caused either by dielectric breakdown or by thermal refiring. The latter can be avoided by devoting new attention to the injection of fresh oil into the arcing chamber. Further study is obviously still needed to correlate all the many and varied test results presented to this year's CIGRE conference, but engineers were hopeful that at the next switchgear discussion in two years' time the state of knowledge of the post-arc period in a circuit-breaking device will have greatly improved, and the results presented this year will become more meaningful.

No new designs of circuit breaker were presented this year, but from America there came news of the successful use of sulphur hexafluoride (SF_6) instead of air for gas-blast circuit breakers. It has considerable advantage in regard to thermal inertia, when compared with air, and economies and improvements in the design of compressors and pipework can be made possible by the use of this gas. The American engineers who presented this paper, Messrs. T. E. Browne, Junior, and W. M. Leeds, said that a high-capacity circuit breaker with a rupturing capacity of 15,000 MVA at 230 kV was now available, using sulphur hexafluoride as the interrupting medium.

On the gas-blast circuit breaker in general, the other new viewpoint came from France, in which it was proposed that gas pressures 10 to 20 times higher than those now used would give greatly improved results, but the research work in this field was still in its infancy.

Submarine Cables

With the continual spread of the distances over

which power systems are interconnected, submarine cables become increasingly important, and it was therefore natural that long-distance submarine transmission was a preferential subject in the cable section of CIGRE. Regarding the type of submarine cable, it had to be admitted that there is no ideal cable yet available, and moreover none of the existing types is suited for laying at great depths. There was a feeling that plastic insulation would be the ideal solution, but no type of plastic cable yet fulfils the requirements for high-voltage submarine cables. From the points of view of simplicity and robustness, the solid type of cable as used for the Gotland scheme linking the island of Gotland with the mainland of Sweden over 61 miles, and using 100 kV d.c., seems to be preferred, whereas its rival for submarine use is the gas pressure pre-impregnated cable, where long lengths can be manufactured, and where the gas pressure tends to keep out the water, or to restrict its ingress in case of damage. Anti-twist armouring will be used to a greater extent, and will become a necessity for cables laid at the deepest limits.

The cable section had before it a lengthy paper from the British and French electricity supply authorities, which will be mentioned later in connection with the direct-current section of CIGRE, but which showed how every possible type of cable design had been examined; and it indicated once again that the solid type was still the only practicable solution. The paper also showed that a novel problem would have to be faced in laying the two cables for the "go" and "return" links of the cross-Channel connection parallel to each other and 10 ft. apart, for the purpose of avoiding magnetic interference with ships' compasses. Lengthy trials were described, in which the cables were laid simultaneously to produce this effect, and undersea television and one-man submarines had subsequently been employed to prove that the cables had been satisfactorily laid with the required spacing

There was an ever-increasing interest in the artificial cooling of cables and the papers and discussions showed that water cooling (both inside the cable and external to its sheath) was now a practical means of increasing the rating of cables by as much as 50%. Considerable developments in this field are to be expected.

Cables have now been made for voltages up to 500 kV and have proved to be entirely satisfactory in practice. The makers did not indicate that there would be any special difficulties in making cables for the increased voltages which are to be expected in the future.

Overhead Lines

Turning now to overhead lines, the papers on towers and tower foundations did not reveal any particularly novel developments, and in the study of vibrations in overhead lines the members agreed that more study was still required before it was possible to state that a particular vibration problem could be solved, or that any exact estimate of the probable vibration on a given overhead line design could be reached. There was a general feeling that there would be changes in line design in the future, and that factors of safety at the moment were on the conservative side. The important aspect of deciding the proper everyday stress values for lines was the subject of much discussion, and there was a collection of data from many countries on the mechanical tensions now found in various designs of overhead line. Wide differences were found, and it is thought that a careful consideration by experts of the data presented to this CIGRE conference would be of value in enabling more economical overhead lines to be designed in the future.

Bundled conductors have come to stay, and three and four conductors in a bundle are now in use in one or two cases, particularly in Russia. There is still no ideal and universally applicable solution to the spacer problem, since spacers of many designs have given trouble, but spring-type devices in which there was no rubbing of bolted or hinged parts were generally thought to be preferable.

Insulators were still the most common cause of overhead-line failures, and a paper presented by Mr. W. Casson, of the Central Electricity Generating Board, Great Britain, was particularly valuable in summarising the results of lengthy investigations into the behaviour of overhead lines on 73 circuits with a total length of 15,456·8 km. These lines were situated in seven countries including Finland, Germany, Great Britain, Japan, Sweden, Russia and the United States. Insulators were responsible for 560 out of 655 faults, which is 85·5% of the total, with conductors being responsible only for 13%, and all other causes such as failure of conductor accessories, troubles with supports and foundations accounting only for 1·5% of the total. The causes of faults were also analysed by Mr. Casson, and his figures showed that natural phenomena, including lightning, accounted for 83·3% of the faults with equipment failures only 8% and "outside agencies" (such as small boys shooting with air guns) only 8·7%. Lightning, thus shown to be the main cause of faults, being responsible for 350 out of 546 incidents due to natural phenomena, can be guarded against by the use of double-earth-wire construction, and the paper said that the performance of lines, in relation to the lightning hazard, is ten times better when fitted with double earth wires than with single wires. As the discussion showed, this is an economic question; the likelihood of insupportable lightning troubles in a particular area must be set against the considerable additional cost of double earth wires along the whole route, involving as it does considerably more complicated supporting structures.

Another method of combating the troubles due to overhead-line faults is that of employing auto-reclosing, and of the 73 circuits investigated, 11 were fitted with single/three-phase reclosure (that is, the circuit breakers would open on one phase only for single-phase to earth faults, and on all phases for multi-phase faults) and 35 for three-phase reclosure, which means that all three phases open for every type of fault. Auto-reclosing was seen to be extremely successful, and particularly with the non-persistent types of line fault such as lightning. It is expected that the extremely comprehensive report and the discussions at CIGRE will hasten the installation of many more auto-reclose circuits in the future.

The only new insulator design was one from France in which a helicoidal shed ran from the top to the bottom of a cylindrical insulator, thus allowing the rain to flow steadily down the whole length of the insulator, acquiring a velocity in so doing which would help in the cleaning action. Pollution of insula-

tors through atmospheric contamination and also from salt spray in areas near the coast was seen to be the biggest problem that transmission engineers concerned with extra-high-voltage lines have to face. The only methods for combating pollution appear to be greasing or live-line washing. British engineers said that on the super-grid system, operating at 275 kV, live-line washing had now been established as perfectly practicable, but greasing was also used. From other parts of the world reports came of satisfactory operation of greased insulators, although it was generally admitted that this was a clumsy method, since the grease had to be renewed about every two years, and this involved an extremely unpleasant, arduous, and lengthly operation.

Protection

Semiconductors were the principal object of discussion in the section on protection and relays. The utilisation of transistor-type relays was said to enable an important reduction to be achieved in the output required from precision-type measuring transformers, by reason of the small power consumption of these relays. This in turn had its effect on design, and it appears possible that it will now be feasible to employ air-core current transformers, so abolishing at one blow problems connected with the saturation of magnetic circuits, particularly by the asymmetric components of fault currents. However, although the results obtained with semiconductors in relay circuits have been encouraging, the general opinion was that they are still on trial in regard to overall reliability and ageing. The behaviour of transistors under transient overvoltages was not yet fully known.

System Operation

There were four main questions raised by the Special Reporter in the section on system operation and planning. First, there was the regulation of the frequency and of the power exchange between interconnected systems. Here it was a question as to whether it would be advisable to reduce the steady-state speed regulation when using regulators of which the range of insensitivity could not be regarded as small or negligible. It seemed preferable to reduce the insensitivity range, in these cases, by using improved regulators, although this raised the question of the adaptation of modern regulators to old power-station plant.

Under this head there was raised the whole question of the automatic control of tie lines between large systems. Certain difficulties in the operation of tie lines where automatic control was in operation were reported from various quarters. However, it seemed clear that in many cases, on large interconnected groups of stations, the frequency control was already better than was strictly speaking necessary, and although there was much discussion, it seemed that only marginal improvements were desirable.

Another section of this group of papers dealt with the operation of networks under transient conditions. Here it was seen that the use of the rotor load angle as a means for additional control of generators is becoming increasingly important. This angle is defined as the mechanical position of the rotor relative to the infinite busbar to which the machine is supposed to be connected, and it can be used as a reliable reference under most operating conditions. In its application, one paper from Great Britain showed how a direct-driven permanent-magnet rotor-angle transmitter could be employed, to actuate an automatic overriding control, responsive directly to the rotor load angle, which would prevent the terminal voltage being adjusted to any value that would permit of the preset maximum rotor angle being exceeded. It was said that this made the new regulator, devised by the General Electric Co. Ltd. of Britain, a combined voltage and rotor-angle controller, and represented a major technical advance in alternator control practice. Its main advantage lay in giving improved stability under transient conditions, while the rotor angle could be displayed on an indicator in the control room and could provide an easily assimilated measurement of stability under all system conditions. This regulator could control large alternators at high leading power factors during light-load periods, and this was highly desirable under modern conditions, particularly when large distances were often involved between generation and load areas.

This section of the conference was notable also for the many references to the increasing use of computers, mainly of the analogue type, in assessing system stability problems.

Extra-High-Voltage Transmission

What is often regarded as the main session in all CIGRE meetings, that dealing with extra-high-voltage a.c. transmission, is discussed elsewhere in this issue in our leading article, but it should be said here that there is still no agreement as to the next voltage step above the present 500 kV level, now the highest voltage in common use, and at present employed only in the U.S.S.R. There was plenty of material, however, on which future decisions in this field could be based.

On the subject of corona loss, it now seems that sufficient data have been accumulated from international sources to enable the average annual losses on a given line construction, and for a given length, to be assessed much more closely than has been the case in the past. For example, a paper from Russia on corona investigation in overhead lines said that a basic parameter, for use with bundles of two, three, or four conductors, was the ratio between the average surface gradient of the conductors and the peak critical visual gradient for the voltage in question. Curves were produced which showed, in relation to this parameter, the ratio between the corona loss and the square of the product of the number of conductors in a bundle multiplied by the radius of one of the conductors. Meteorological conditions were divided into four classes, each having a standard curve.

In connection with the allied problem of radio and television interference, it seemed that only by the very slow accumulation of enormous amounts of statistical data will it be possible to evolve rules whereby this important and difficult source of annoyance caused by extra-high-voltage overhead lines can be overcome. CIGRE plays an important part here by bringing together much of this information, so that geographical, atmospheric and operational data could be allied to design data, to estimate the influence of all the very many factors which together lay at the root of interference trouble. No particular conclusions were reached on this occasion.

High-Voltage Direct Current

Perhaps the greatest advance reported at the 1960 CIGRE conference was in the field of high-voltage direct-current power transmission. This advance was not so much the inception of any new project in this field, in addition to those now in operation or under construction, but in the almost universally accepted viewpoint, expressed for the first time, that direct current has taken its place as a perfectly practicable and a reasonably well proved system for bulk power transmission over long distances.

This viewpoint was particularly expressed by the Central Electricity Generating Board engineers from Britain, who were now so convinced of the need for accelerated development in the direct-current field that they have decided to establish a major testing station in an old power station in North London, in which direct-current transfer of up to 83 MW between the two ends of the test station can be achieved. With the Channel cable approaching completion, and with reports of the increasingly successful and reliable operation of the Sweden-Gotland scheme, and further with the 800 kV Stalingrad-Donbass d.c. line under construction, there is much activity on the d.c. front.

Hydro-electric engineers do not need to be reminded of one particular advantage of high-voltage direct current: the ability to operate a station or a group of stations in an asynchronous method, or the ability for different frequency levels to be adopted when needed by hydraulic conditions in any plants linked to the main system by d.c. means.

The paper produced by the French and British supply engineers, mentioned earlier, proved that with two large systems such as the French and the British, joined together by a 160 MW link, asynchronous a.c. operation would have been almost impossible. This paper also shows, once again, that the design problems of a major link of this type, involving a submarine crossing, had now all been solved, and the authors were confident that the operational problems were also susceptible of prediction and solution.

While this CIGRE meeting may not have been a vintage year, in the sense of providing novel ideas and devices in many of its sections, nevertheless it was as important as ever in giving an up-to-date survey of progress in all fields of electrical power transmission, which is obviously playing a rapidly increasing part in the economic life of every nation in the world.

Boreholes Drilled with a Neyrfor Turbodrill

Exploratory boreholes were recently drilled on the site of the Meffrouch dam in Algeria with a Neyrfor turbodrill. It was the first time that a Neyrfor turbodrill had been used for such work. The job was completed successfully without any other special equipment having to be used. Meffrouch dam will supply the Oran and Tlemcen regions with drinking water and may also provide head for an impulse turbine. It will be a multiple-arch dam 25 m. high, consisting of prefabricated units, with buttresses set at 25 m. centres. In order to investigate the nature of the underlying rocks, it was necessary to excavate two 1·5 m. diameter, 30 m. deep shafts in a dolomite formation where pneumatic drills were of little use. To avoid this difficulty it was planned to drill seven approximately 312 mm. holes for each shaft, one at the centre and six on the circumference using conventional rotary drilling equipment. Pneumatic drills would then be used to remove the remaining rock. This method had to be abandoned after the first attempt since too much time had to be spent in moving the rig around the circumference of the shaft.

Travaux Souterrains Limited then decided to use a Neyrfor 7¼ in. O.D. turbodrill in conjunction with a

Fig. 1. A general view of Meffrouch dam

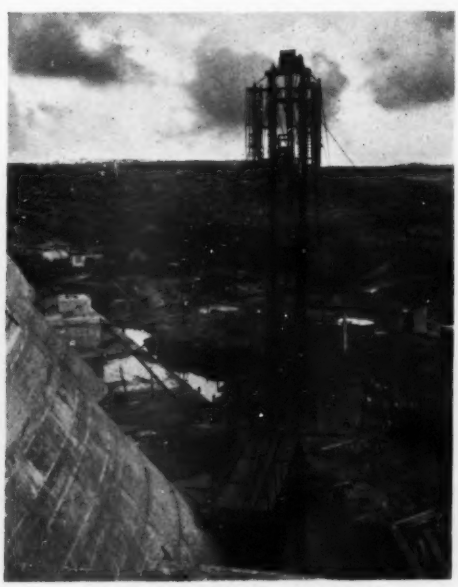


Fig. 2. The Neyrfor drilling rig

drilling rig owned by Forasol Limited. It then became possible to drill all seven holes for one shaft without moving the drilling rig. The turbodrill was fitted with specially designed S.M.F. three-cutter bits, the weight on the bit being approximately 5 tons and the circulation rate 2,350 litres per minute. The holes for the two 30 m. deep shafts were drilled at a penetration rate of approximately 10 m. per hour. The turbodrill was then used to drill five 1·5 m. diameter, 10 m. deep, dam inspection shafts. An ordinary crane was used for this work instead of a drilling rig, and the turbodrill casing was prevented from rotating by means of drilling tongs. The ease with which an adequately powered Neyrfor turbodrill can be used for such work and the considerable amount of time thus saved, would appear to indicate that there is great scope for turbodrills in the drilling of shallow exploratory boreholes in rather hard formations.

A fuller description of the turbodrill has already appeared in WATER POWER, June 1956, p. 236.

Calgary Power Company

Engineers began to investigate the storage possibilities of diverting the Spray River into the large valley of the Spray Lakes as early as 1911. Calgary Power began its study of the valley's potential in 1921. As the result of intensive survey during 1947 and 1948, construction was commenced for the development of this area which lies 1,100 feet above the Bow Valley. Its waters now pass through six hydro plants, supplying power to much of Alberta's domestic, farm, commercial and industrial consumers.

Construction of plant extensions at Spray and Rundle plants near Banff, Alberta, is nearing completion. The installation of second turbo generators at each plant will add 102,000 h.p. to the system, bringing total generating capacity of Calgary Power Ltd. to over 650,000 h.p. The new units are expected to be on line this autumn.

Completing the 64-ft. surge tank for the Spray plant extension

Both plants are supplied with water from the Spray reservoir which lies behind Three Sisters Mountain. The reservoir is twenty miles long and stores some 210,000 acre-ft. of water. Along with eight other hydro plants operated by the Company along the Bow Valley, Spray and Rundle are remotely controlled from Seebe. Automatic control equipment for the additional units is now being assembled.

New Boving Butterfly Valves

Boving and Co. Ltd., of 41/47, Strand, London, W.C.2, have recently introduced a completely new range of oleo-pneumatic auto-closing butterfly valves.

Boving butterfly valve and control cabinet

They incorporate several advantages over conventional butterfly and reflux valves, stemming from the asymmetrical blade design and the flexibility of the oleo-pneumatic package operating units.

The torque characteristics of the asymmetric blade make it possible to use the valve as a combined stop and non-return valve. Full flow in the normal direction exerts a closing torque on the blade at all angles from fully closed through approximately 84° to within 6° of the fully open position. At this point the torque reverses and the blade is then held in the fully open position as long as the flow continues in the same direction, until closed by the ram.

If the direction of flow reverses a closing torque is exerted on the blade at all angles from fully open to fully closed. The blade design also contributes to droptight sealing.

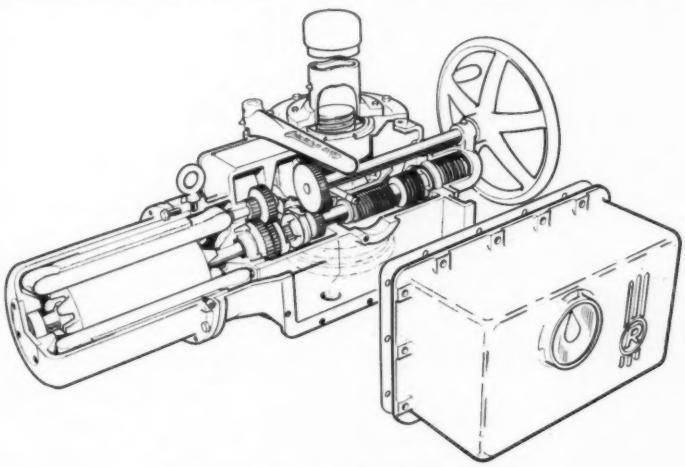
The flexibility of the control system means that opening and closing times may easily be varied to suit pipeline operating conditions. The control can be varied for many different applications including

normal power-operated opening and closing, and power-operated opening and closing incorporating a "cracked" open position. The control cabinet is weatherproof and can be used to operate the valve by pushbutton remote control.

The new butterfly valves are available in a range of sizes from 12 in. to 120 in. in diameter, and larger sizes can be made to order.

Actuators for Valve Control

A wide range of actuators for the control of valves has been developed by Rotork Engineering Co. Ltd., Widcombe Manor, Bath, Somerset. The company,



Dissected view of the Rotork actuator

which claims to be the first to specialise only in actuators, was set up with the concept of serving the valve industry with a range of apparatus to motorise any valve.

The actuators are usually powered by electric motors, but others are available which are powered either pneumatically or hydraulically. The actuator motor is controlled by reversing contactors operated by pushbuttons or by automatic switches from a distance. To impose a travel limitation on the valve spindle, a combination of torque and limit switches is provided. The torque switch, which is adjusted to 10% of the actuator rating, has the valuable feature of protecting against obstruction such as valve seizure, and of stopping the actuator at the end positions. The limit switches are geared directly to the valve position and thus control the in-between points of opening and closure. Another interesting feature is that the available torque can be increased by a "hammerblow" effect to unseat a tightly closed valve. The effect is provided by allowing the motor to reach its full speed before engaging the slow-speed drive. This utilises peak torque rather than starting torque, plus the flywheel effect. Other features of the Rotork actuator are its variable-speed operation, interlocking sequence, and a system enabling the valve to follow a varying signal automatically so as to maintain constant levels in reservoirs, or constant flows. This system has been found to be particularly useful and is envisaged in the actuators for the penstocks for the new Bristol stormwater interceptor tunnel where the tunnel flow will be adjusted to follow a flood-level signal originating three miles upstream.

Rotork Engineering Co. Ltd. has already concluded agreements for the manufacture of these actuators on the Continent with Neyrpic S.A. of France, the E.N.I. Group, Nuoro Pignone of Italy, and Zimmerman and Jantsen G.m.b.H. of Germany.

Firth Cleveland Flowmetering Equipment

Firth Cleveland Instruments Limited, Treforest, Glamorgan, have developed a range of equipment for the accurate measurement of the rate of flow of liquids. Firth Cleveland turbine flowmeters (Series EF 1030) are available for flow rates from 0·25 to 10,000 g.p.m. and are claimed to be accurate to $\pm 0{\cdot}5\%$ over a 10 : 1 flow range.

The flowmeter consists of a non-magnetic pipe-like housing, containing a magnetic stainless-steel multi-bladed rotor. Outside the pipe section a screw-in magnetic pick-up coil assembly is fitted. When a liquid is passing through the meter, the rotor revolves at a speed proportional to the rate of liquid flow. As each rotor blade passes the pick-up coil, the magnetic field generated by the permanent magnet (contained within the coil) induces an alternating voltage across the coil. The frequency of the induced voltage is proportional to the volumetric flow rate, while the total number of pulses generated is exactly proportional to the quantity of liquid metered. The output signal can be fed to instruments indicating respectively the rate of flow or totalised flow.

Caps for Concrete Vibrators

The life of a pneumatic poker-type concrete vibrator can be appreciably lengthened by reasonable care in handling, the most frequent cause of wear being due to external shocks transmitted to the poker when vibrating at frequencies of around 8,000 per minute. Many of these shocks arise from the poker being allowed to strike some unyielding object such as

C.P. vibrator poker caps

exists at the base of a pour, and with this in mind, The Consolidated Pneumatic Tool Co. Ltd., 232 Dawes Road, London, S.W.6, have recently introduced two sizes of rubber caps to fit their models 325 and 5180 poker vibrators respectively. The caps are of thick moulded rubber and have been designed to absorb the major portion of the blow arising from striking solid objects.

Book Reviews

Statistical Year-Book of the World Power Conference. Edited by Frederick Brown, B.Sc.(Econ.), F.S.S. No. 9. Published by Percy Lund, Humphries & Co. Ltd., 12 Bedford Square, London, W.C.1., on behalf of The Central Office of The World Power Conference. 1960. 216 pp. 11 in. × 8½ × ¾ in. Cloth bound. Price £3 10s. 0d. net.

This book contains statistics of the resources, production, stocks, imports, exports and consumption of power in all the countries of the world from which it was possible to obtain information. The statistics are the latest available and relate to 1954, 1955, 1956, 1957 and, in some cases, to 1958.

A table is given of the area of the various countries together with an estimate of the population. The statistics are dealt with under the headings: Coal, brown coal, lignite, peat, wood, petroleum, benzole, alcohols, natural gas, manufactured gas, and water power. In regard to water power it is shown that the increase over the years 1954–1957 was about 20%.

It may sometimes be found that there is inconsistency between the figures in this volume and the corresponding figures in other publications, even when the latter were also obtained from official sources. Except in some cases where the divergence arises from an official revision of statistics, the inconsistency is only apparent and is due to a difference in definition—for example, small productive units may be included in the compilation in one set of figures and omitted in the other. Readers who find such inconsistencies should compare the definitions printed in this volume with those used in compiling the "inconsistent" figure, and choose the one which is most suitable for their particular purpose.

Die Reuss (The Reuss River), a reprint of the special issue of "Wasser- und Energiewirtschaft," published by Schweizerischer Wasserverband (Swiss Water Association), St. Petersstrasse 10, Zurich 1, on the occasion of its 50th anniversary; 8 in. by 11½ in., 88 pp., 91 ff. Price in Switzerland, Swiss Fr. 8.

The part played in the energy economy of Switzerland by the Reuss River—a sub-tributary of the Rhine through the Aare—appears clearly from the table printed on pp. 42/43, which lists 32 plants in operation or in course of construction. These aggregate 439,195 kW in maximum capacity, and 1,517·36 GWh in production, with a useful storage of 134 million cu. m., corresponding to 241·7 GWh. Installations below 1,000 kW are not included in these figures. Out of the 11 articles of this publication devoted directly or indirectly to water power, we should like to single out "Water-Power Development in the Reuss Basin," by Dipl. Ing. Josef Blanchart, a general survey of the projects completed or in progress in the catchment area of the river, from which it appears that, upon completion of the projects now in course of elaboration, the aggregate production of the basin could reach 2,500 GWh. A full description is given of the Göschenen group of plants, by Dr. Ing. Willy Eggenberger, a scheme which, when completed, will have a total capacity of 192,500 kW and a yearly production of 425 GWh. This includes a description of the Göschenen Alp earthfill dam, the highest and one of the largest structures of its kind in the world. This description is supplemented by a paper on the geotechnical investigations of the Göschenenalp subsoil by Professor G. Schnitter and Dipl. Ing. Jürg Zeller, of the Laboratory for Hydraulic and Earth Structures at the Federal University in Zurich.

River Forecasting on the Hungarian Danube. Proceedings of the Hungarian Research Institute for Water Resources. No. 6. Compiled by K. Szesztay, Cand. of Eng. Sc. Budapest. 1959.

This methodical study gives an account of the results of the work carried out during the years 1955–58 in the Research Institute for Water Resources concerning the streamflow forecasting of the Danube River. In Chapters I and II of the paper are discussed in detail the problems of flood-peak forecasting, on the basis of the peaks observed on the upper reaches of the river as well as of the precipitation on the catchment area, using the graphs elaborated for the reach between Bratislava (Pozsony, in Hungary) and Mohács as examples. In Chapter III, a method for continuous day-to-day discharge and stage forecasting is presented, on the basis of which forecasts are prepared for the Hungarian Danube one to four days in advance. The forecasts are based on empirical relations determined by methods of graphical correlation. The many basic data and computation charts appended may be useful in other works concerning the water régime of the river or in testing other methods of river forecasting.

Les Barrages de Vallée (Storage Dams), by Dr. Ing. Heinrich Press, Professor at the Berlin-Charlottenburg Technical University, translated by J. Schmitt, ingénieur E.T.P., with a foreword by M. Mary, chairman of the French Committee of the International Commission on Large Dams. Published by Dunod, 92, rue Bonaparte, Paris-VIe, 6·2 in. by 9·5 in., XII–276 pp., 326 ff. Price in France, paper covers, Fr. 3,550.

There is really very little we could add to our review of the original German edition of this volume (WATER POWER, December 1954, p. 448). No doubt some sections, such as that on the advantages and disadvantages of fill structures, would have gained by being treated less succinctly, but it should not be forgotten that the work was intended as a textbook for technological schools. As such it lacks nothing in thoroughness, all the essentials are condensed in a mininmum of space, without losing anything in value as a reference book for practical engineers. Besides, as far as the text alone is concerned, there is practically no difference between this first French

edition and the second, enlarged German edition (WATER POWER, July 1959, p. 276) published at about the same time, the enlargements of the latter extending almost exclusively to illustrations. From the production point of view, the book leaves nothing to be desired. Full marks are extended to the translator for an outstanding achievement.

The Electric Power Situation in Europe in 1958/59 and its Future Prospects (ST/ECE/EP/2), can be obtained from United Nations Economic Commission for Europe, Geneva. Price $0·75, 5s. stg., Sw. Fr. 3·00, or the equivalent in local currencies.

This annual report, which analyses various developments in the electric power industry, contains for the first time more detailed information concerning medium-term forecasts. These imply that average European requirements per head in 1965 will be 2,050 kWh, representing an average rise in consumption of 9 per cent. over 1955, compared with a rise of 9·3 per cent. between 1951 and 1955. The composition of these total requirements is not expected to change much. Although the ranking in consumption per head will, on the available evidence, not be greatly affected up to 1965, the estimated rates of increase are, with some exceptions, inversely proportional to the consumption levels already reached. Average consumption per head in 1975 might reach 3,700 kWh, a mean increase of 7·4 per cent. between 1966 and 1975.

The Report contains six chapters: consumption of electric power in 1958, future tendencies in electric power consumption, generating capacity, transmission networks and international exchange of electric power, capital expenditure and related economic questions, and summary and conclusions. Most of the information contained in this document has been supplied by members of the ECE in reply to the annual questionnaire circulated by the Secretariat.

Taschenbuch Wasserkraftanlagen (Water-Power Engineering Pocket-Book), by Obering. A. Rauch, published by Franckh'sche Verlagshandlung W. Keller & Co., Stuttgart-O; 4 in. by 6 in., 430 pp., 366 diagrams, and 54 plates with 98 photographic illustrations. Price in Germany, bound in leatherette, DM. 34.

This newcomer to the Franckh collection of pocket-size reference books is, we believe, the first work of its kind published in Germany on water-power engineering. It is divided into 14 sections which cover all the aspects of the subject-matter. Fundamentals, restricted to a minimum, are followed by chapters on turbines, weirs, control valves and gates, channels, canals, tunnels, surge tanks and pipelines; there is also a special chapter on couplings, clutches and gearing. Chapter VIII deals with power-station planning, and reviews the various types of hydro-electric developments. It also contains short paragraphs on landscape protection, noise prevention in hydro-plants, and turbine reception tests. A whole section is devoted to various examples of reconstruction schemes occurring in actual practice, especially in connection with older, small-size plants. Chapter X describes various patterns of adaptation of hydro-electric installations to the surrounding landscape. Chapter XI is of particular interest, it describes and reviews various instances of medium-sized and major reservoir-powered plants as well as of pumped-storage installations, with particular stress on turbines and their design and construction. Eight pages on axial pumps are appended to this section. Chapter XII covers the problems connected with the operation and care of power stations and their equipment, as well as the maintenance work involved, and is followed by a short chapter on the electric equipment of hydro plants. A series of tables, particularly well-selected photographic views of existing installations and their equipment, a short bibliography, a subject-index and an index of the photographic illustrations conclude the volume. The symbols throughout the book are those in general use in Germany. In spite of their reduced size, the illustrations, both line and photographic, are excellent. The work is exceedingly well produced.

Recommendations for Voltage Measurement by Means of Sphere Gaps (I.E.C. Publication 52, Second edition). International Electrotechnical Commission, 1 rue de Varembé, Geneva. Price, Sw. F. 8.

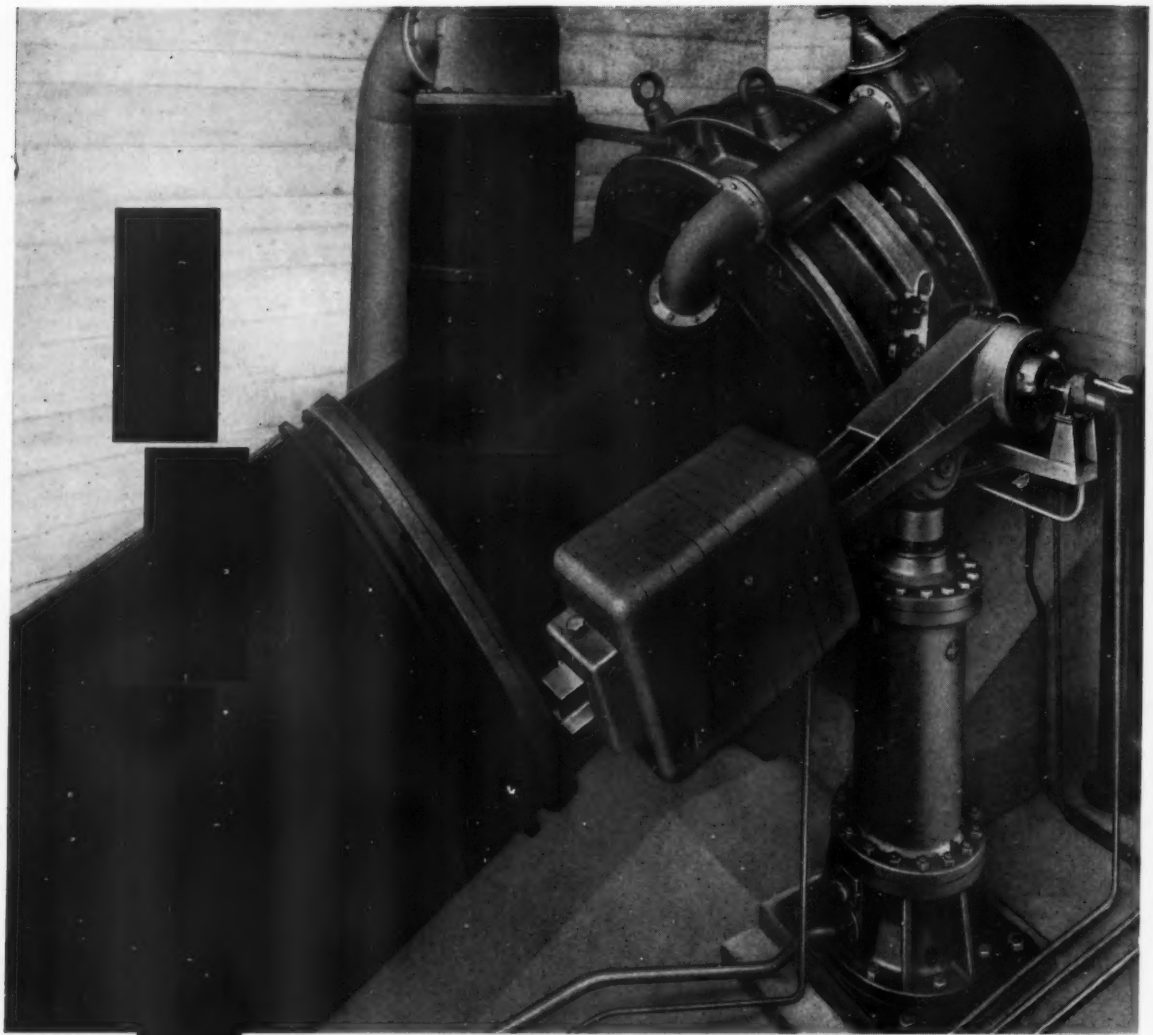
This publication represents a compromise that has been accepted by almost all National Committees of the I.E.C. and is a truly international publication on the measurement of voltage by means of sphere gaps. It applies to the measurement of the peak value of alternating voltages, full standard or longer-tailed impulse voltages. Rules are given for the construction of standard sphere gaps and their use, and the peak values of the disruptive voltages in air for various spacings between the spheres are given in tabular form.

Vesitalous (Finnish Journal of Water Economy, Hydraulic and Agricultural Engineering). Vol. 1, No. 1, 1960. Published four times annually. Editor-in-Chief, Aimo Maasilta. Kaisaniemenkatu 2b, Helsinki, Finland.

We extend a welcome to this neatly produced Finnish technical journal, which will appear quarterly and will deal with water conservation and related matters. The text, of course, is in Finnish, but two pages are devoted to English abstracts (in excellent English) of the main articles in the issue. For this first issue the articles deal with the regulation of Lake Saimaa, water economy and nature conservation, the foundations of small houses, Lake Höytiäinen, the regulation of Lake Kirkkojärvi, water supply projects in Finland, and water conservation in England. The effect of regulation on certain Finnish water-power plants is mentioned, but judging from this first issue, the major preoccupation of the journal seems to be water conservation rather than hydro-electric development.

Scientific Russian by G. Condoyannis. Published by Chapman and Hall Limited, 37 Essex Street, London, W.C.2. 225 pp. Price 28s. net.

Engineers and scientists are sometimes faced with the problem of acquiring an adequate knowledge of reading Russian to cope with technical articles in their particular fields. This book has been prepared to be used, in conjunction with a dictionary, almost from the beginning with such unsimplified technical reading matter Most language textbooks tend to instruct the learner on how to reproduce Russian for use in speaking or writing, whereas this book teaches the basic structure of the language aimed for reading.



DE ROLL Butterfly Valve,
automatically shutting
in the event of penstock rupture,
at Ernen Power Station (Switzerland),
nominal diameter 1900 mm (75 in.),
working pressure 4,8 kg/cm² (68 psi),
with weight Drive for shutting
and oil-pressure operated Servomotor
for opening

322

This is the stone
that makes
the tower
stand or fall.
In a Power Station
it is the **Shut-off Valves**
that provide for the safety
of the entire plant
and thereby
make it stand or fall

DE ROLL

Shut-off Valves

our speciality

DE ROLL Iron Works, Klus (Switzerland)

Abstracts from the World Technical Press

Suction Slots in Overfall Weirs

As far back as 1951 Professor Escande showed that by applying to overflow dams and weirs the principle of boundary-layer suction, crests can be obtained with a high discharge coefficient, exceeding by 15 to 20% that of the conventional Creager crest. To prevent nappe separation, which occurs above a certain load, on the downstream face of a non-streamlined crest, it is enough to provide along the whole length of the crest for a suction slot opening on to a collecting drain which empties through a pipe downstream from the structure. The whole system, that is to say the slot, collecting drain and outlet pipe, primes syphon-like automatically, and nappe separation stops. The authors discuss the design of this type of crest, the main characteristics of which were determined by numerous model tests, and subsequently checked by experiments on large-scale models. Discharge coefficients, suction discharge, distribution of pressures on the crest, and influence of the downstream water level, are dealt with in separate paragraphs. The final section of the paper reviews the test devoted to automatic priming, the disturbing influence of piers and gates, as well as the perturbations caused by foreign bodies carried by the flow. The characteristics of a half-scale prototype weir are to be ascertained by a series of experiments to be carried out in the large flume of the Laboratory of Hydraulics at Toulouse University. (Professor Escande and F. Sananes, *Mémoires et Travaux de la Société Hydrotechnique de France*, Vol. II, 1959, p. 124; *La Houille Blanche*, Vol. XIV, No. B, December 1959, p. 892; 11 pp., 8 ff.)

Developing the Upper Valais

Hydro-electrically, the Upper Valais region is that stretch of the Rhône upstream of Brigue, about 25 miles in length, where a considerable number of small mountain streams fall on either bank. While the Lower Valais has been practically fully developed, no comprehensive attempt has been made to regularise the discharge of the Upper Rhône and its affluents, and harness their waters for energy production. After ten years of investigations the Federal and Cantonal authorities finally approved the project submitted by the Geneva "Société Générale pour l'Industrie." The project is based on the wide difference in character between the two slopes of the valley. The right flank is ruled by the Grosser Aletschgletscher, Switzerland's largest glacier and its slightly smaller neighbour, the Fieschergletscher, thus carrying an enormous summer discharge and unimportant winter flows. On the left bank there is a much weaker glaciation giving a much more regular hydraulic régime. On the other hand, geologically, the right slopes of the valley are of a much better quality and lend themselves much more favourably to the setting up of hydro-electric installations. The project is therefore confined to the right bank of the Rhône, while the left-bank tributaries remain earmarked for diversion at a later date to a new downstream plant which will be generously equipped to cope with the otherwise unstorable peak discharge of the summer months. In outline, the project consists of two stages with underground power station at Bitsch (75·5 MW), near the confluence of the Massa with the Rhône, and Gebidem (26 MW), where a cavern will be excavated on the right bank of the 200,000 cu. m. reservoir provided on the upper course of the Massa stream. A third stage is contemplated at a later date on the headwaters of the Rhône, with an underground power station at Oberwald, fed from the 100 million cu. m. Gletscher reservoir. (Denis Blondel, *Wasser- & Energiewirtschaft—Cours d'Eau et Energie*, Vol. 51, No. 11, November 1959, p. 303, 5 pp. in French, 3 ff.)

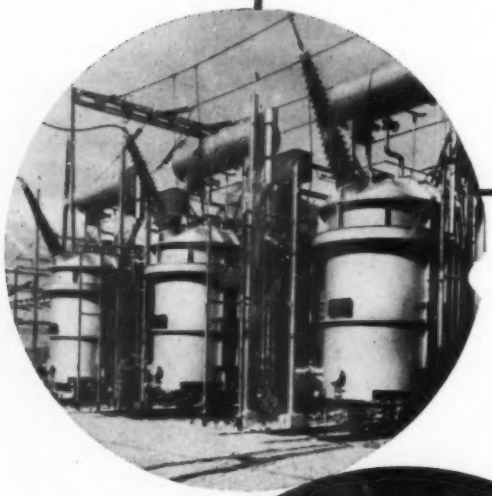
NOTE. The above issue contains an account of the inauguration of two new plants in Switzerland, Ackersand II and Melchsee-Frucht, the Swiss-German plant at Rheinau, and the two groups of plants, Zervreila and Gougra.

A New Tunnelling Machine

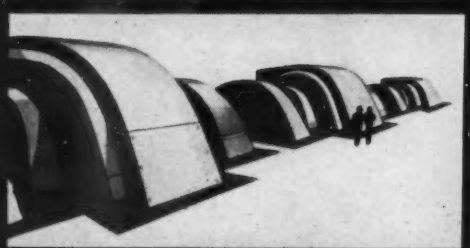
The "Teredo" tunneller described in this article differs from most recent machines of the same class in two marked respects: its cutting equipment and its mucking method. It is a cylindrical shield 11½ ft. in diameter and 30 ft. long, built in three sections: nose, middle section and tail. The nose section, equipped with a cutting edge of 1 in. steel, is steel bulkheaded a few inches behind the leading edge, and the cutting equipment—an arm carrying a cutter chain and rotating like a clock hand—operates in front of the bulkhead. The space between bulkhead and tunnel is kept flooded with about 5 ft. of water. Cuttings drop into the water and the mixture is sucked out through the 6 in. intake pipe of a wobble-shaft pump inside the shield. The muck line, which is lengthened as the shield advances, discharges to the same area throughout the job, about 12,000 gallons of the clay-water mixture being moved per hour. The machine is propelled by eighteen 25 ton hydraulic jacks. After each 8 ft. of advance, an 8 ft. increment of the tunnel is concreted. The Houston contractor, Elmer C. Gardner, banking on the yet-to-be-proven performance of the machine he designed with the help of his men, took a sewer tunnelling contract in Houston 30% under his closest competitor. He claims his confidence was justified as the soil encountered along the tunnel route consisted mostly of "joint" clay. Whether the machine can be adapted to work successfully in rock remains to be seen. (*Engineering News-Record*, December 3, 1959, pp. 43/44, 3 ff.)

Pore Pressure in Pressure Tunnels

The first part of this article is devoted to an investigation of the elastic equilibrium occurring, generally, in a thick-wall conduit submitted to an internal pressure, and in some cases, to conduits of infinite thickness, such as tunnels. Pressure is first assumed to be applied to the external wall of a thick cylinder, and then, at a given distance from the axis of the cylinder. Radial pressure distribution is assumed to be the same as applying to a flow in a porous medium, in which case the pressure can be determined by Darcy's Law. In the second part of the article, the study extends to the state of equilibrium existing in a pressure tunnel driven in the rock, and it is assumed that the behaviour of the rock is identical with that of a thoroughly porous body. Important deductions are drawn with regard to the equilibrium



Power Stations and Substations



Sécheron

Sécheron Works Co Ltd, Geneva, the specialists in the electrotechnical field, supply all kinds of equipment for complete power stations and substations:

High capacity A.C. and D.C. motors and generators. Power transformers of all sizes and voltages. Automatic regulators for various types of controls. Pumpless mercury arc rectifiers, semi-conductor rectifiers.

Further lines of production: Electric traction equipment, Welding sets and electrodes.

S.A. des Ateliers de Sécheron, Geneva, Switzerland

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occurring in the lining of pressure tunnels, especially in instances in which pressure varies as a function of time. The pressures affecting both sides of the lining depend to a wide extent upon the relative permeability of the materials under investigation. We have to deal here with a problem which belongs to the sphere of "underground" hydraulics. This leads to the conclusion that purely mechanical stress computations, based on the usual assumptions relating to the pressure to which the internal surface of the cylinder is subjected, are hardly of any significance. (G. Sauvage de Saint-Marc, M. Bouvard, and Ma Min-Yuan, *La Houille Blanche*, Vol. 15, No. 2, March-April 1960. p. 173, 21 pp., 4 ff.).

Biggest Pumped-Storage Project in U.S.A.

Union Electric Company of St. Louis has been awarded a $20 million first contract for construction of the biggest pumped-storage electric generating plant in the U.S.A. This project, which will ultimately cost $50 million, is unconnected with any natural hydro-electric source. Reversible pump-turbines at a 370 acre pool on the east fork of the Black River at Taum Sauk Creek will use power at night from steam-generating plants in the St. Louis area to lift water to a smaller 50 acre pool on a nearby hill 1,000 ft. high. During day time the plant will add 350 MW to the peak power capacity of the utility system. Major economies will result for the system from this development, which, in addition, will defer for two years the necessity of starting work on a new steam-generating plant. (*Engineering News-Record*, December 24, 1959, p. 24, 1 f.)

Wertach River Development

It is not very often that a multi-purpose hydro-electric system is built for the main purpose of stabilising the level of the ground-water table. The development of the Wertach River between Ettringen and Augsburg is such a case. The constant scouring of the bed of this Lech tributary was found to cause such a lowering of the water table that the surrounding agricultural region was in danger of becoming an arid strip of land. To check this danger, the Lech-Elektrizitäts-Werke have divided the stretch of river involved into stages which will also be harnessed for energy generation by means of spillweirs. The Schwabmünchen plant, described in detail in this article, and erected 3 km. from the locality of the same name, is the first stage and its switchyard will eventually become the central control point of the whole system. Owing to the relatively small yearly output of the scheme, its profitability can be ensured only by the utmost economy in both construction and operation. Automation is therefore to be applied to the fullest possible extent. The Schwabmünchen installations consist of a 18 m. long two-bay spillweir block with bottom outlet gates and top flap gates designed for a discharge capacity of 610 cu. m. per sec. On the right bank is a power block housing a vertical-shaft 3,600 h.p. Storek Kaplan turbine which drives a synchronous generator fitted for easier paralleling with a large damper winding. The power block is equipped with a fine trashrack and cleaner, a stoplog gate, a stop gate for the draft tube, and a travelling service crane which also attends to the spillweir gates. The top edge of the trashrack lies below the level of the headrace water, so as to avoid freezing of the rack in cold weather. The earthfill dykes on either bank reach a height of 3 m. at the plant, gradually decreasing upstream according to the natural gradient of the river. The storage pool extends to about 1·6 km. in length. The turbine operates from a head of 9·6 m. at 200 r.p.m. (runaway speed 535 r.p.m.). The four adjustable blades of its runner are made of 13% chrome steel and are no more than 15 mm. thick at their outer edges, so that at the high runner speed losses are reduced to a minimum and a good degree of efficiency is achieved. After 20,000 hours of operation, no signs of cavitation could be detected on the runner itself, its pit, or on any other part of the machine. The plant is fulfilling its main purpose of satisfactorily stabilising the level of the ground-water table in its area. (Herbert Storek, *Die Wasserwirtschaft*, Vol. 49, No. 12, December 1959, p. 320, 5 pp., 8 ff.)

Improving Flow Gauging in Connection with Hydro-electric Developments

This paper reviews in detail the setting up, recommissioning and calibrating of five gauging stations of the Romanche basin in connection with the systematic range of investigations undertaken by EDF for the purpose of improving flow gauging in streams to be harnessed for energy generation. The flow measurements taken in the Romanche basin are described in detail, and the design and standardisation of various types of gauging stations are discussed, stress being laid on improvements especially suited to the conditions obtaining in the Alps and other high mountainous regions. From the two Romanche plants, St. Guillerme (11 cu. m. per sec.) and Chambon (12 cu. m. per sec.), the former was selected for measuring the turbine discharge because of its constant gross head, whereas at Chambon the head is widely variable. On the other hand, the discharge capacity of the Chambon spillway was checked by the chemical method (bichromate dilution). At two other points, spillway discharge was measured by means of an improved slot-type flow gauge designed by the General Technical Division of EDF. (M. André, EDF, *Mémoires et Travaux de la Société Hydrotechnique de France*, Vol. II, 1959, p. 155; *La Houille Blanche*, Vol. XIV, No. B, December 1959, p. 923; 11 pp., 9 ff.)

Is the Buttress Dam Taboo in U.S.A.?

This is the question an experienced dam designer of international repute is asking when confronted by the fact that, while high buttress dams are extensively used abroad, no such structures of any consequence have been built in the U.S. since the early forties. Are U.S.A. dam builders over-cautious or unduly suspicious of these structures? The author examines the various deterrents to the widespread use of buttress designs—more time required by buttressing the construction, large amount of reinforcing steel required, difficulty in checking seepage between buttress heads, greater susceptibility to damage from freezing and thawing, greater vulnerability to earthquakes and, in wartime, to enemy action. He then asserts that all these deterrents can be obviated by suitable design and improved, modern construction. Attention is drawn in particular to the success achieved by the Marcello-type dam. The various design elements are examined—shape of head, slope and buttress thickness, joints between neighbouring buttress heads, and types of foundation. It is admitted that all types of buttress dams require more form-

work than the conventional gravity dam, which means to say that the unit cost of concrete in the former is higher than in the latter, and an analysis based on U.S. conditions shows that although the gravity structure requires about 34% more concrete than the buttress type, the unit cost of concrete in the latter is 30% higher. This is contested, however, on the basis of actual experience by Italian designers and builders, who have estimated that a hollow gravity dam is cheaper than a solid gravity structure if the height exceeds 55 ft. The author advocates the selection of the massive buttress dam in preference to the solid gravity dam for certain locations, whenever their advantages are emphasised by such factors as the shortage of cement and aggregates, remoteness of site, and lower labour wages. Other arguments than theoretical design considerations and predictable economy need to be answered for U.S. dam builders before the buttress type will be acceptable to them. (G. S. Sarkaria, *Engineering News-Record*, Vol. 164, No. 13, March 31, 1960, p. 30, 5 pp., 6 ff.).

Pirttikoski Power Project

A detailed description is given of the two 60 MW vertical-shaft Kaplan turbines installed at the underground power house of the Pirttikoski plant (WATER POWER, March 1959, p. 86). The first generating set has been in service since December 1959, and the second was scheduled for commissioning in April 1960. (Ing. H. Obrist, Escher Wyss AG, *Schweizerische Bauzeitung*, Vol. 78, No. 9, February 25, 1960, p. 123, 4 pp., 5 ff.)

Waterhammer Studies

The purpose of this paper is to draw attention to several theoretical and practical waterhammer problems which have been investigated in recent years by Czechoslovak research organisations and engineering works. A description is given of the ČKD-type surge suppressor which is still extensively used in Czechoslovakia in the delivery mains of pumping stations. Following a short paragraph on waterhammer in the cooling system of condensing steam power plants, the author deals with the phenomenon such as it occurs in the pressure conduits of pumped-storage hydro-electric systems. (Dipl. Ing. Lev Pavluch, *Czechoslovak Heavy Industry*, English Edition, No. 3/1960, p. 7, 9 pp., 17 ff.)

NOTE. The above issue also contains an article by Dipl. Ing. Josef Hušek on storage and other pumps used in hydro-electric plant (p. 25, 5 pp., 10 ff.).

Rio Santa Development

This Peruvian plant at Cañon del Pato serving the Chimbote steelworks is described in detail. Hydro-electric plant and steelworks, both owned by Corporación Peruana del Santo, were put into service together at the beginning of 1958. Two short paragraphs on the geography and climate of Peru and on the hydrological conditions of the 4,897 sq. km. Rio Santa catchment lead to the description of the development. This has the following main features: (1) a gravity overflow dam 35 m. long 20 m. high above foundations with a gravel trap protecting the intake; (2) an underground four-gallery cellular desilter of the Neyrpic-Gariel type, receiving the power water from the intake through a tunnel 560 m. long and 6 m. wide; (3) a concreted horseshoe-section power tunnel 9,100 m. long and 5·4 m. wide, designed for the ultimate discharge of 48 cu. m. per sec. (six generating sets), and protected over the last 20 m. by a cylindrical welded steel lining 5·6 m. diameter and 10 mm. thick; (4) a distribution chamber 40 m. long and 5 m. in diameter between the power tunnel and the pressure shafts, but since the scheme now operates with only one pressure shaft and two turbines, the chamber is temporarily restricted to a length of 26 m. by a steel plate which will enable the steel lining to be extended to its end-stage length without any substantial interruption in the service of the two first-stage generating units; (5) an underground surge chamber with non-overflow top expansion tank, and a connecting shaft at the junction of the power tunnel and the distribution chamber; (6) No. 1 pressure shaft, 430 m. long, decreasing in diameter from 2·2 m. at the top to 2·08 m. and finally to 1·95 m.; (7) a service shaft, also 430 m. long, between the machine hall and the outdoor platform at the upstream end of the pressure shafts, housing a lift and an emergency ladder, as well as the cables connecting with the overhead transmission line and those controlling the head gates; (8) an underground machine hall 110 m. by 9·52 m. in plan and 14·51 m. high, designed for housing the six 25 MW sets of the ultimate generating equipment, and connecting with the right bank of the river near Huallanca by a tunnel 370 m. long, 4·4 m. wide, 5·3 m. high; (9) a 470 m. long, 5·5 m. wide horseshoe-section tailrace tunnel discharging into the Rio Santa valley at a safe height above flood level. The two horizontal-shaft generating sets now in service consist each of two double-jet Pelton wheels aggregating 35,000 h.p. in output and 8 cu. m. per sec. in discharge, mounted on either end of the shaft of a 27,500 kVA alternator, and operating at 450 r.p.m. from a net head of 400 m. Most of the civil-engineering works are built to fit the ultimate equipment of the plant and the total diverted discharge of 48 cu. m. per sec. Corporación Peruana del Santa are now contemplating to construct on the river, at a later date, a storage reservoir which would regulate the flow and increase the output of the Cañon del Pato plant during the dry season. If other storage facilities are provided on the lakes and right-bank tributaries, the Santa Valley and the Chimbote region, backed by an installed capacity of 400 MW and a yearly production of 3,000 million kWh could develop into a great industrial zone. (H. Bégui, *Construction*, Vol. XIV, No. 12, December 1959, p. 353, 14 ff.)

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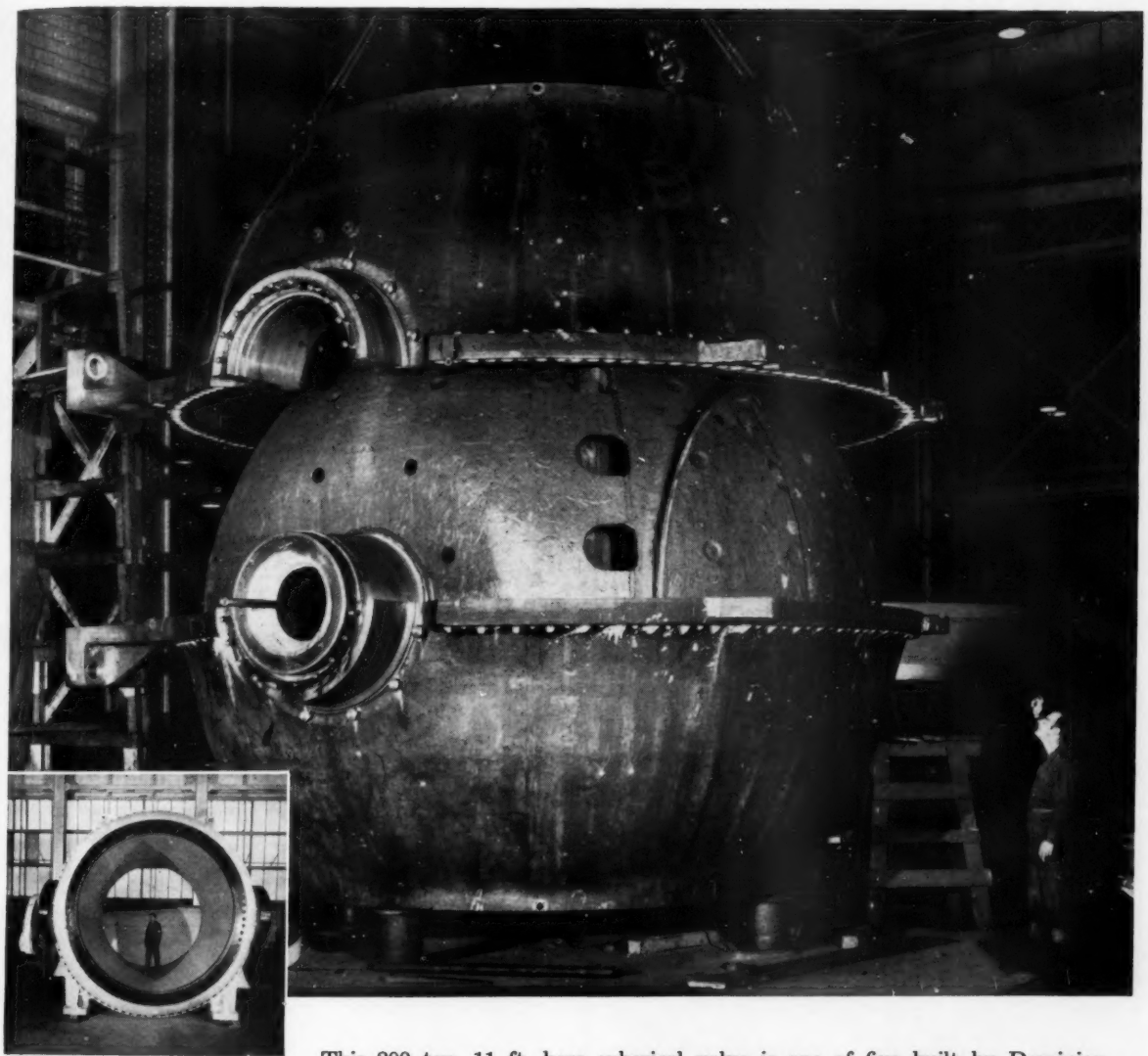

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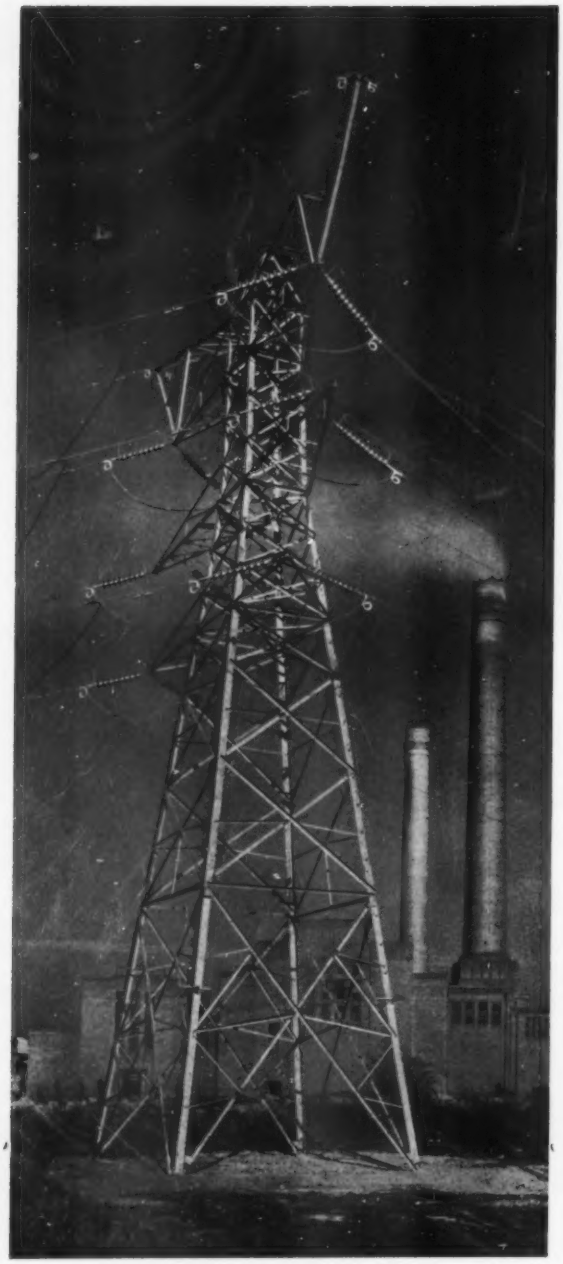

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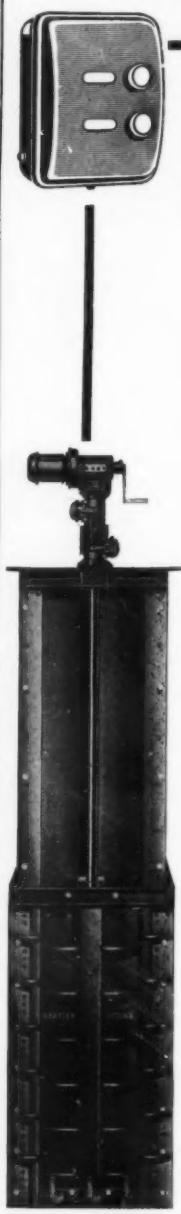

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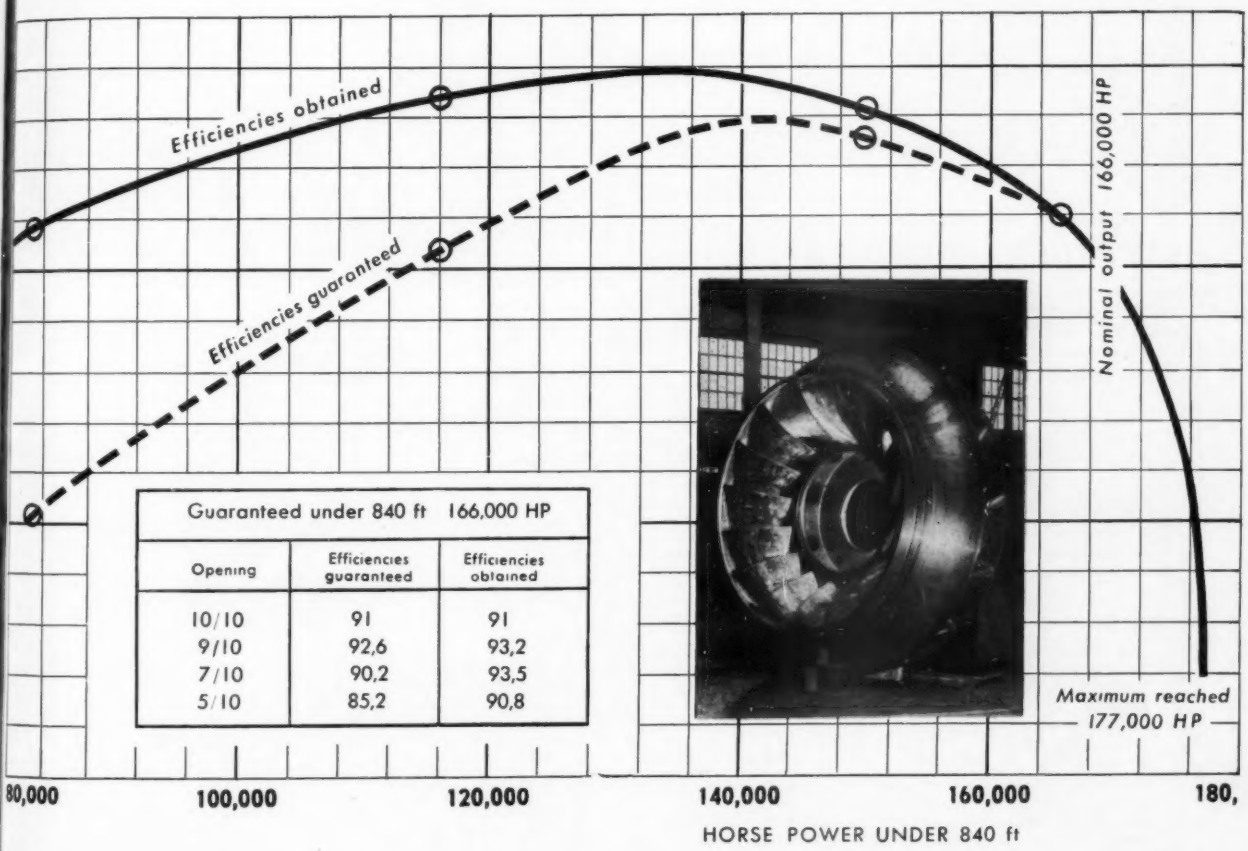

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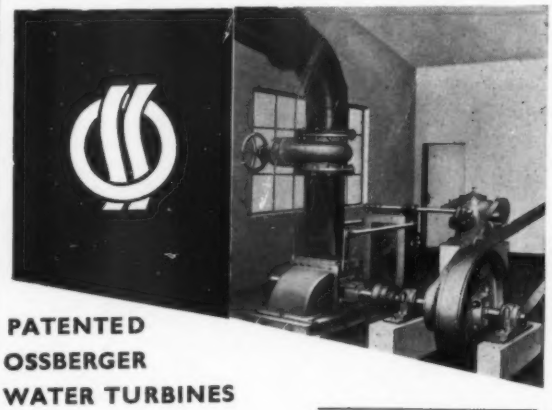

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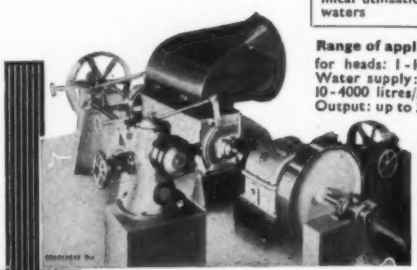

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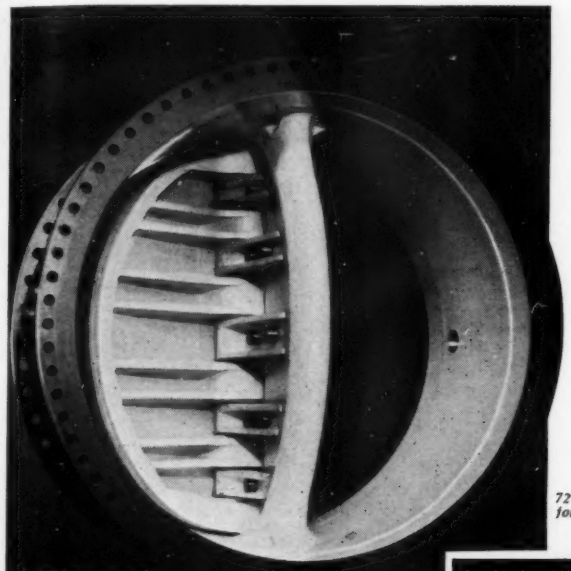

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A

A.C. Plant & Hire Co. Ltd., The ... —
Acciaieria E Tubificio Di Brescia ... 8
Allen, W. G. & Sons (Tipton) Ltd. ... —
Allgemeine Elektricitäts-Gesellschaft ... 41
Alimark Verken 4
Allis-Chalmers Hydraulic Division ... —
Allmanna Svenska Electriska Aktiebolaget ... —
Aluminium Wire & Cable Co. Ltd. ... —
Anderson, Grice, The Company, Ltd. ... —
Ansaldo San Giorgio, S.p.A. 22
Ardelt Industries of Canada Ltd. ... —
Armfield Hydraulic Engineering Co. Ltd. ... —
Associated Electrical Industries (Manchester) Ltd. —
Associated Electrical Industries (Woolwich) Ltd. ... 56
Associated Electrical Industries (Rugby) Ltd. Outside Back Cover
Ateliers de Constructions Electriques de Della ... 10
Atlas Copco, A.B. ... ... 26 & 27

B

Balfour, Beatty & Co. Ltd. ... ... —
Bell, Theodore & Co. Ltd. ... ... —
Birkett, T. M., Billington & Newton Ltd. ... ... —
Bochumer Verein ... ... Inside Back Cover
Bouchayer & Viallet ... ... —
Boving & Co. Ltd. 5
Boyles Bros. Drilling Co. Ltd. ... —
British Insulated Callender's Cables Ltd. ... 7
British Pitometer, The Co., Ltd. ... —
British Ropeway Engineering Co. Ltd. ... —
Brown, Boveri & Co. Ltd. 19
Bruce, Peebles & Co. Ltd. 47
Bucyrus-Erie Co. Ltd. 55
Buss, A.G. 48
Butters Bros. & Co. Ltd. 40

C

Canadian General Electric Co. Ltd. ... —
Canadian Vickers Ltd. 14
Canadian Wood Pipe & Tanks Ltd. ... 54
Cementation Co. Ltd. ... ... —
Ceretti & Tanfani Ropeway Co. Ltd. ... —
Charmilles Engineering Works Ltd. ... —
Cockburns Ltd. 17
Compagnie Industrielle de Travaux ... —
Consolidated Pneumatic Tool Co. Ltd. ... 62
Costruzioni Generali Farsura Cogefar ... —
Craelius Co. Ltd. ... ... —
Crompton Parkinson (Export) Ltd. ... —

D

De Havilland Propellers Ltd. ... —
de Roll, Louis, Ironworks Ltd. ... 63
Dominion Engineering Co. Ltd. ... 65
Doulton Industrial Porcelains Ltd. ... —
Drees & Co., G.m.b.H. ... ... —
Dresser Manufacturing Division ... —

E

Eimco (Gt. Britain) Ltd. ... —
ELIN, A.G. ... ... —
Elliott Bros. (London) Ltd. ... —
English Electric Co. Ltd. 3
English Steel Forge & Engineering Corporation Ltd. —
Escher Wyss Ltd. 53

F

Ferranti Ltd. 45
Ferrum Montage 35
Fischer, Ltd., George ... ... —

G

Galileo Officine di Battaglia Terme ... —
General Electric Co. Ltd. ... ... Front Cover
Gilbert Gilkes & Gordon Ltd. 50
Giovanola Freres, S.A. 44
Glenfield & Kennedy Ltd. 31
J. Gordon Valves Ltd. 69

H

Harland Engineering Co. Ltd., The 60
Hartley's (Stoke-on-Trent) Ltd. 66
Henderson, John M. & Co. Ltd. 39
Henley's W. T., Telegraph Works Co. Ltd. ... ... —
Heywood & Co. Ltd. ... ... —
Hilger & Watts Ltd. ... ... —
Hitachi Ltd. 28
Holland & Hannen and Cubitts Ltd. ... ... —
Holman Bros. Ltd. ... ... —
Horseley Bridge & Thos. Piggott Ltd. ... ... —
Huhn, G. 69
Hydraulics & Pneumatics Ltd. ... ... —

I

Impresit Kariba (Pvt) Ltd. ... ... —
Ingersoll-Rand Co., Inc. ... ... —
International Engineering Co., Inc. ... ... —
International General Electric Co. ... ... 42 & 43

J

Jonneret, S.A. Ateliers de Construction ... ... —
Joy-Sullivan Ltd. ... ... —

K

Karlstads Mekaniska Werkstad, Akt. 37
Krupp, Fried. Maschinen- und Stahlbau ... ... —
Kuljian Corporation, The 58
Kvaerner Brug ... ... —

L

Leffel, James & Company, The 16
Lepper Transformatorenwerk August 38
Le Materiel Electrique, S-W ... ... —

M

Magrini, S.p.A. 52
Mannesmann-Export, G.m.b.H. ... ... —
Marelli, Ercole & Co., S.p.A. ... ... —
Maschinenfabrik Augsburg-Nurnberg, A.G. 13
Maschinenfabrik Edward Ruch ... ... —
Maschinenfabrik B. Maier ... ... —
Micanite & Insulators Co. Ltd., The ... ... —
Michell Bearings Ltd. 69
Mitchell Construction Co., The 21
Mitsubishi Electric Manufacturing Co. 33
Mobil Oil Co. Ltd. ... ... —
Murray, D. J., Manufacturing Co. 29

N

Newport News Shipbuilding & Dry Dock Co. ... —
Neyrpic 67
Nippon Gaishi Kaisha Ltd. 6
Nuttall, E., Son & Co. (London) Ltd. ... ... —
Nydqvist & Holm, A/B ... ... —

O

Oerlikon Engineering Company ... ... —
Ossberger Turbinenfabrik 68

P

Phoenix-Rheinrohr, A.G. ... ... —
Pirelli-General Cable Works Ltd. 9

R

Ransomes & Rapier Ltd. 32
Reyrolle, A. & Co. Ltd. ... ... Inside Front Cover
Rheinstahl Union Brückenbau-Akt. Ges. ... ... —
Rip Bits Ltd. ... ... —
Riva Costruzioni Meccaniche ... ... —
Rosenthal Isolatoren, G.m.b.H. 68
Rotork Engineering Co. Ltd. ... ... —
Ruhrstahl, A.G. ... ... —
Ruston Bucyrus Ltd. ... ... —

S

S. A. Ateliers De Secheron 64
SACE Costruzioni Elettromeccaniche ... ... —
Sakai Iron Works Co. Ltd. 59
Salvi, A. & Co. 18
Salzgitter Maschinen Aktiengesellschaft 36
Savoisienne 11
Scarpa & Magnano 12
Shell International Petroleum Co. ... ... —
Short Bros. & Harland Ltd. ... ... —
Siemens-Schuckertwerke, A.G. ... ... —
Smith, Fredk. & Co. ... ... —
Smith, S. Morgan Company ... ... —
Soc. p. Az. Cementi Armati Ing. Manelli 20
Societa Elettro-Morsetterie Volpato ... ... —
Societe Dauphinoise d'Etudes & de Montages ... —
Societa Nazionale Delle Officine Di Savigliano ... —
Societe des Forges et Ateliers Du Creusot ... ... —
Standard Telephones & Cables Ltd. ... ... —
Steatite & Porcelain Products Ltd. 46
Storey, Thos. (Engineers) Ltd. ... ... —
Strachan & Henshaw Ltd. ... ... —
Sulzer Bros. (London) Ltd. ... ... —
Svenska Metallverken, A/B 15

T

Tampella OY 23
Technoexport 34
Tees Side Bridge & Engineering Works Ltd. ... 66
Tokyo Shibaura Electric Co. Ltd. 30
Torno, Giuseppe & Co. 51
Tosi, Franco, S.p.A. 49

V

Vereinigte Osterreichische Eisen- und Stahlwerke 24 & 25
Victor Products Ltd. ... ... —
Vevey Engineering Works Ltd. ... ... —
Voith, J. M., G.m.b.H. 57

W

Waagner Biro ... ... —
White, R. & Sons (Engineers) Ltd. ... ... —
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Y

Yorkshire Electric Transformer Co. Ltd. ... ... —

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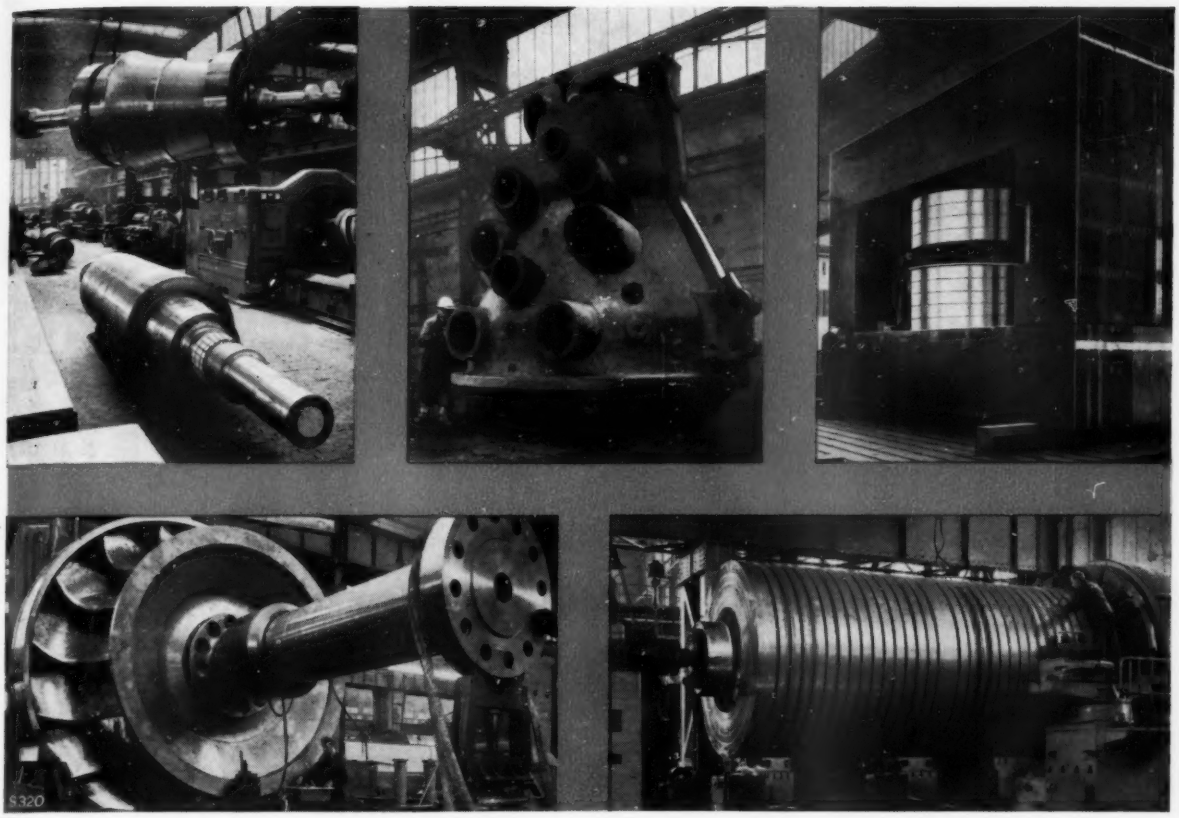

The most economical use of sources of energy

such as water, coal, oil and atoms depends very largely on the choice of the right steels for the construction of the power plants and units. High pressures, high temperatures, and scale, corrosion and cavitation resistance call for steel castings and forgings specially suited to these requirements. The extremely high stresses in modern steam-raising plants are marked by working temperatures up to 650° C, and gas turbines operate at even higher temperatures.

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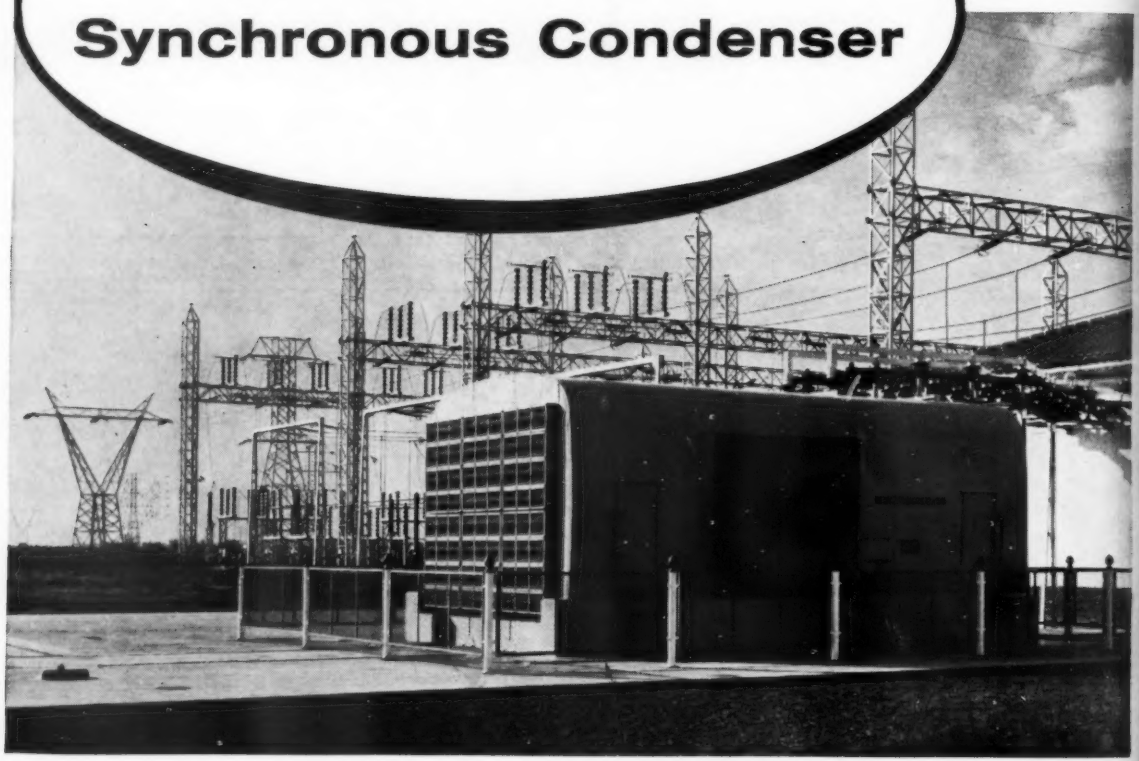
AEI 125-ton Synchronous Condenser



... erected with a 5-ton crane

This air-cooled outdoor-type AEI synchronous condenser, rated at 50,000 kVA 1,000 r.p.m., is in service at the Torrente (Spain) substation of Hidroeléctrica Española S.A. Despite the large capacity of the machine, its design permitted erection without the use of a heavy crane, the only equipment necessary being jacks, rollers, and a 5-ton hoist.

AEI Synchronous Condensers are in service in every continent

Sizes range from 1,000 kVA upwards, and total capacity installed or on order exceeds 700,000 kVA.

Enquiries relating to synchronous condensers should be addressed to Large Electrical Machine Sales, Rugby.

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